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USER'S GUIDE FOR PAL
A Gaussian-Plume Algorithm for Point, Area, and Line Sources

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Calculations are performed for each hour. The hourly meteorological data required are wind direction, wind speed, stability class, and mixing height. Single values of each of these four parameters are assumed representative for the area modeled.

This algorithm is not intended for application to entire urban areas but is intended, rather, to assess the impact on air quality, on scales of tens to hundreds of meters, of portions of urban areas such as shopping centers, large parking areas, and airports. Level terrain is assumed.

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USER'S GUIDE FOR PAL

A GAUSSIAN-PLUME ALGORITHM FOR POINT, AREA, AND LINE SOURCES

by

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AUTHOR'S AFFILIATION

The author, William B. Petersen, is on assignment with the U.S. Environmental Protection Agency from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

PREFACE

The Users' Guide for PAL was written so that one need not understand the mathematical formulation to apply the model. However, I strongly recommend that the user carefully read Sections 2 and 4, which give valuable insight into the model's flexibility and limitations, and the assignment of values to input parameters.

Although the user's guide is complete in itself, the user may wish to avoid the step of going from the printed page to a computer source program by utilizing the PAL program in UNAMAP (Users Network for Applied Modeling of Air Pollution), either by executing on the nationwide network or by obtaining the source code on magnetic tape (Users Network for Applied Modeling of Air Pollution (UNAMAP), Accession No. PB 229-771, from NTIS, Springfield, VA, 22151).

While attempts are made to thoroughly check out computer programs with a wide variety of data, errors are found occasionally. In case there is a need to correct, revise, or update this model, revisions will be distributed in the same manner as this report. If your copy was obtained by purchase or special order, you may obtain revisions as they are issued by completing the mailing form on the last page of this report.

Comments and suggestions regarding this document should be directed to Chief, Environmental Applications Branch, Meteorology and Assessment Division, (Mail Drop 80), EPA, Research Triangle Park, NC 27711.

ABSTRACT

PAL is an acronym for this point, area, and line source algorithm. PAL is a method of estimating short-term dispersion using Gaussian-plume steady-state assumptions. The algorithm can be used for estimating concentrations of non-reactive pollutants at 30 receptors for averaging times of from 1 to 24 hours, and for a limited number of point, area, and line sources (30 of each type).

Calculations are performed for each hour. The hourly meteorological data required are wind direction, wind speed, stability class, and mixing height. Single values of each of these four parameters are assumed representative for the area modeled.

This algorithm is not intended for application to entire urban areas but is intended, rather, to assess the impact on air quality, on scales of tens to hundreds of meters, of portions of urban areas such as shopping centers, large parking areas, and airports. Level terrain is assumed.

The Gaussian point source equation estimates concentrations from point sources after determining the effective height of emission and the upwind and crosswind distance of the source from the receptor.

Numerical integration of the Gaussian point source equation is used to determine concentrations from the four types of line sources. Subroutines are included that estimate concentrations for multiplelane line and curved path sources, special line sources (line sources with endpoints at different heights above ground), and special curved path sources.

Integration over the area source which includes edge effects from the source region is done by considering finite line sources perpendicular to the wind at intervals upwind from the receptor. The crosswind integration is done analytically; integration upwind is done numerically by successive approximations.

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1. INTRODUCTION

The first two sections of the User's Guide for PAL should be beneficial to those determining the applicability of PAL to their particular need.

PAL is a multisource Gaussian-Plume atmospheric dispersion algorithm for estimating concentrations of non-reactive pollutants. Concentration estimates are based on hourly meteorology, and averages can be computed for averaging times from 1 to 24 hours. Six source types are included in PAL: point, area, two types of line sources, and two types of curved path sources. As many as 30 sources may be included under each source type. PAL is not intended as an urban-wide model but may be applied to estimate the contribution of part of an urban area to the concentration. Portions of urban areas assessed by PAL for impact on air quality are:

- Industrial complexes
- Sports stadiums
- Parking lots
- Shopping areas
- Airports

At the heart of PAL is the Gaussian-Plume point source equation (Gifford, 1960). The equation is used directly in the computations for point, line, and curved path sources, and in a modified form for area sources. The point source algorithm is very similar to the point source models provided on the UNAMAP tape (Hosler, 1975). A unique feature of PAL is the computational technique for estimating the concentration from area sources. This technique incorporates edge effects and is theoretically more accurate than the methods used in the Climatological Dispersion Model (CDM) (Busse and Zimmerman, 1973) and the Air Quality Display Model (AQDM) (Martin, 1971). The horizontal line source algorithm is similar to the Highway Air Pollution Model (HIWAY) (Zimmerman and Thompson, 1975). Input source types also include two types of curved paths, one of which considers variation of emissions along the path. PAL will also estimate concentrations from a line source which has a variation in emission along the source. This line source may be slanted or elevated relative to the ground. PAL offers considerable flexibility to the user. Any or all of the six source subroutines may be utilized. The user also has the options of employing an hourly variation to emission rates and of allowing the wind speed to change with height. Concentration estimates can be made at up to 30 user specified receptor locations.

The User's Guide includes sections on the features and limitations for use of PAL, the organization of the computer program, a description of input data, and an example problem with computer output. A technical discussion of PAL is presented in Appendix A, and a listing of the source code is available in Appendix B.

2. FEATURES AND LIMITATIONS

The analysis power available to the user of PAL cannot be appreciated unless two features of the model are understood. One feature of the model concerns the handling of the wind speed. While the user is specifying the kinds of source types which will later be input in the problem, the user also specifies whether the wind speed varies as a function of height. The wind speed can be held constant or can be varied as a function of height and stability class. The manner in which the wind speed is handled within PAL is specified for each source type, allowing considerable flexibility. A second feature of the model concerns how the emission rates from the various input sources are determined. Unlike some multisource models, such as the Real-Time Air-Quality Model (RAM) (Novak and Turner, 1976), the emissions data for each source type is input into the model only once and is not initialized for each hour of meteorology. However, as each hour of meteorology is input, the user can specify, independently for each source type, the fractional amount of the initial input emission rate to be applied. For instance, say we had specified the maximum sulfur dioxide (SO_2) emission rate for a situation in which we had only point and area sources. From insight into the situation, we might know that the point sources contribute most during the daylight hours from factory emissions, and that the area sources contribute most during the nighttime hours from home heating. We could model the above hypothetical situation by appropriately varying the emission factors, individually for each source type, for each hour of a 24-hour period (refer to Meteorological Data, Appendix A for further discussion). The wind speed feature and the emission rate feature are extremely powerful when considered with the various restarting options of the program (A, B, and C of Figure 1).

PAL, as other Gaussian models, is subject to Gaussian dispersion assumptions, such as conservation of mass, steady state atmospheric conditions, and relatively flat terrain. Complex aerodynamic effects, like downwash from buildings, are not considered in PAL. However, enhanced dispersion can be simulated by modifying the dispersion parameters to account for initial mixing caused by buildings. The detail which PAL considers, such as edge effects from area sources and the finite length of line sources, generally prohibits the application of PAL to an entire urban area due to excessive computer cost. Also, since meteorological data are entered hour by hour, a normal run for PAL would be to simulate a period of 1 to 24 hours. Calculations for more than several 24-hour periods would also be costly. The principal use of PAL is to estimate the increase in pollutant concentration over that due to other sources not included in the PAL computation.

In Gaussian models concentration estimates are inversely proportional to the wind speed. Besides the unreasonably high concentration estimates calculated during very low wind speed conditions due to this inverse relationship, there are other modeling difficulties associated with low wind speeds. Wind directions may be extremely variable. Thus, the hour average wind direction used in the model may well not be a true representation of the wind direction during the hour. The dispersion parameters used in PAL do not account for this kind of variability in the wind. Because of the extreme variability of the wind direction, actual concentrations might well be much lower than model estimates. Gaussian models also assume that there is no build-up of pollutant from hour to hour. That is, the concentration estimate made for a particular hour is independent of the concentration estimate made for the meteorology of the previous hour. However, during low wind speed conditions pollutant build-up may occur, particularly for an urban area or a section of an urban area. A reasonable lower limit of wind speed to use as input into PAL is 1.0 m $\sec^{-1}$.

Care must also be exercised when computing high average concentration estimates to compare with air quality standards, say for example 8 hours. It would be unrealistic to assume that a combination of wind direction, wind speed, and stability class would persist during an 8-hour period. The persistence of the above variables can be obtained from meteorological records and should be used accordingly in the model.

PAL is designed to make estimates over relatively level terrain. Receptor height should not be used in an attempt to simulate topographic differences. The height of the receptor is the height of that receptor above the local ground level, not the height of the ground above some reference plane.

The Pasquill-Gifford horizontal dispersion parameter values used in PAL are strictly applicable only to concentration estimates with a 3-minute averaging time (Pasquill, 1976). An increase would be expected in horizontal dispersion for averaging times of 1 hour. As on-site measurements of turbulence statistics become more routinely available and the state-of-the-art in dispersion modeling improves, PAL could be easily modified to incorporate such advances. The dispersion parameters in PAL are applicable for rural environments. However, a recommendation is made in Section 4 to account for the increase dispersion in urban areas by appropriate change of stability category. Finally, PAL does not require any tape drives or external files for storage. Storage requirements are approximately 27K words. The example problem (Section 5) used 21.8 seconds of computer time on the UNIVAC 1110 at a cost of $0.78.

3. ORGANIZATION OF COMPUTER PROGRAM

The general framework of PAL is discussed in this section. It is intended to give the reader a general knowledge of the computer program, rather than a detailed description of each subroutine. Such detailed descriptions are seldom very profitable without an understanding of the source code and are of little value in the application of the algorithm. The general flow of PAL, the structure of the computer subroutines and the computer functions, and a brief description of each subroutine and function are included in this section.

GENERAL FLOW OF THE MODEL

Figure 1 depicts the general flow of the model. The main routine reads control information to determine the integration accuracy for the area and line sources, the options to be employed if the wind speed change with height and variation of emission factors are to be used, and the source types to be used. After reading the control information, the source data are expected depending upon the indicated controls. Any number or combination of the six source types may be used. All input to the program is printed as output before execution so that a complete listing is available (see Section 5). Finally, receptor coordinates and meteorological data are read. Meteorological data are required for each hour up to 24 hours.

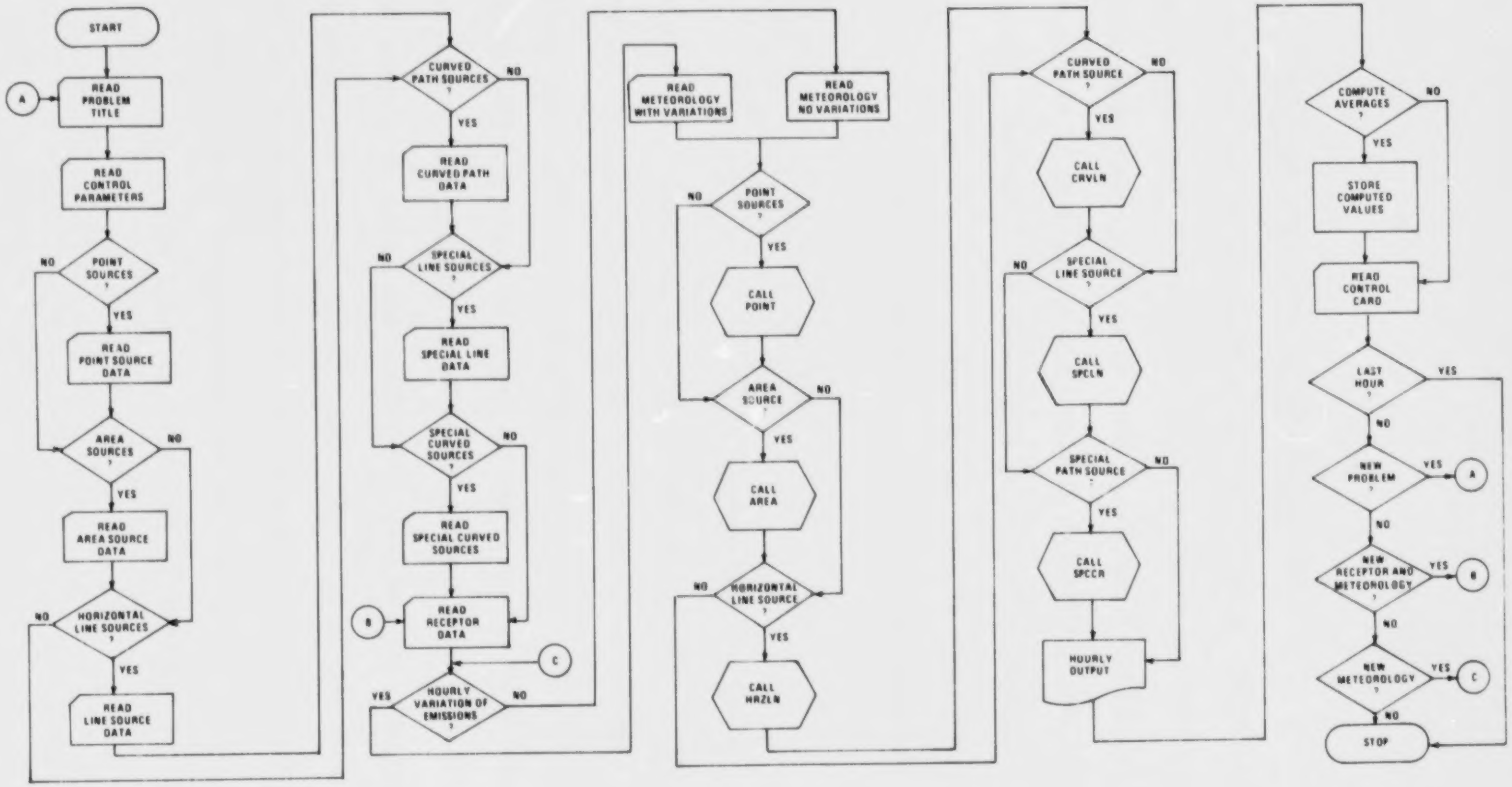
START
A
READ PROBLEM TITLE
READ CONTROL PARAMETERS
POINT SOURCES ?
NO
YES
READ POINT SOURCE DATA
AREA SOURCES ?
NO
YES
READ AREA SOURCE DATA
HORIZONTAL LINE SOURCES ?
NO
YES
READ LINE SOURCE DATA
CURVED PATH SOURCES ?
NO
YES
READ CURVED PATH DATA
SPECIAL LINE SOURCES ?
NO
YES
READ SPECIAL LINE DATA
SPECIAL CURVED SOURCES ?
NO
YES
READ SPECIAL CURVED SOURCES
B
READ RECEPTOR DATA
C
HOURLY VARIATION OF EMISSIONS ?
YES
NO
READ METEOROLOGY WITH VARIATIONS
READ METEOROLOGY NO VARIATIONS
POINT SOURCES ?
NO
YES
CALL POINT
AREA SOURCE ?
NO
YES
CALL AREA
HORIZONTAL LINE SOURCE ?
NO
YES
CALL HRZLN
CURVED PATH SOURCE ?
NO
YES
CALL CRVLN
SPECIAL LINE SOURCE ?
NO
YES
CALL SPCLN
SPECIAL PATH SOURCE ?
NO
YES
CALL SPCCR
HOURLY OUTPUT
COMPUTE AVERAGES ?
NO
YES
STORE COMPUTED VALUES
READ CONTROL CARD
LAST HOUR ?
YES
NO
NEW PROBLEM ?
YES
A
NO
NEW RECEPTOR AND METEOROLOGY ?
YES
B
NO
NEW METEOROLOGY ?
YES
C
NO
STOP

Figure 1. General flow diagram for PAL.

STRUCTURE OF PROGRAM

Figure 2 shows the structure of the subroutines and functions. "PAL" is the main routine; it reads input data and stores the appropriate data in common with the six major subroutines. All input data for each hour are read before execution begins on any source type. A brief description of the main program, subroutines, and functions follows.

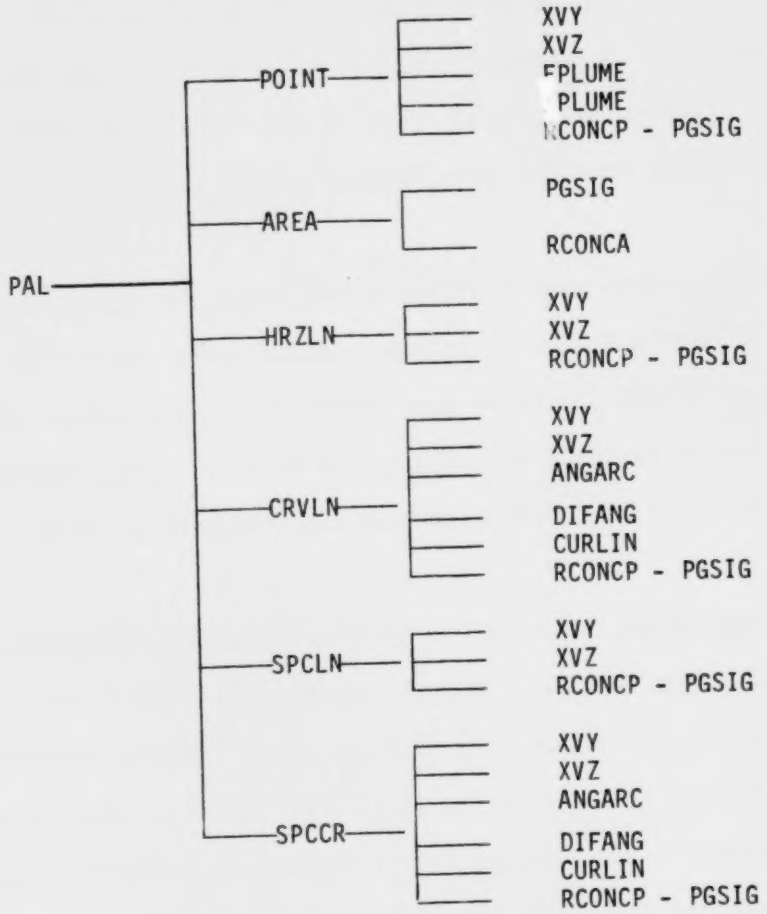
PAL
POINT
XVY
XVZ
FPLUME
PLUME
RCONCP - PGSIG
AREA
PGSIG
RCONCA
HRZLN
XVY
XVZ
RCONCP - PGSIG
CRVLN
XVY
XVZ
ANGARC
DIFANG
CURLIN
RCONCP - PGSIG
SPCLN
XVY
XVZ
RCONCP - PGSIG
SPCCR
XVY
XVZ
ANGARC
DIFANG
CURLIN
RCONCP - PGSIG

Figure 2. Structure of subroutines and functions.

DESCRIPTION OF SUBROUTINES AND FUNCTIONS

Each subroutine and function of PAL is briefly described in the following pages.

PAL - PAL is the main program that reads in all input data. Source input data cards include point, area, horizontal line, special line, horizontal curved path, and special curved path sources. Subroutines are called for each source type. Any combination, or all, of the above subroutines can be called by PAL. Input data cards for receptor location and hourly meteorology are required and not optional input as the above. PAL prints out all input data and concentration estimates.

POINT - This subroutine is called by PAL and makes concentration estimates for point sources. POINT calls subroutines XPLUME and FPLUME for plume rise calculation. Subroutine RCONCP is called by POINT to estimate the relative concentration for a receptor at a given downwind and crosswind distance.

AREA - This subroutine is called by PAL and makes concentration estimates from area sources. AREA calls RCONCA, which calculates the relative concentration for a receptor downwind of an infinite line source. PGSIG is also called by AREA to determine sigma y (σ_y) and sigma z (σ_z) for a given stability class and downwind distance. The concentration from area sources is approximated by numerical integration in the upwind direction of the concentration from infinite crosswind line sources corrected for finite crosswind length.

HRZLN - This subroutine is called by PAL and makes concentration estimates for multilane horizontal line sources. Functions XVY and XVZ are called by HRZLN to calculate the virtual distance necessary to account for the initial crosswind and vertical dispersion, which is specified by the user. Subroutine RCONCP, called by HRZLN, estimates the relative concentration for a receptor at a given downwind and crosswind distance.

CRVLN - This subroutine is called by PAL and makes concentration estimates from multilane horizontal curved path sources. CRVLN calls two subroutines, CURLIN and RCONCP. CURLIN calculates the coordinates, if any, of the intersection points of the curved path and the upwind projection from the receptor coordinates. Subroutine RCONCP and functions XVY and XVZ are called by CRVLN and have the same function as they do in HRZLN. The shape of the curved path is approximated by an arc from a circle, determined from the three points on the curved path specified by the user.

SPCLN - This subroutine is called by PAL and makes concentration estimates from special line sources. SPCLN calls subroutine RCONCP and functions XVY and XVZ, which are used in the same manner as in HRZLN. The line sources do not have to be horizontal and emissions per unit length are allowed to vary.

SPCCR - This subroutine is called by PAL and makes concentration estimates from special curved path sources. Subroutines CURLIN and RCONCP and functions XVY, XVZ, DIFANG and ANGARC are called by SPCCR and are used in the same manner as in CRVLN. The special curved path sources must be horizontal but will allow emissions per unit length to vary along the curved path.

XPLUME - This subroutine is called by POINT and calculates the plume rise at a given downwind distance x.

FPLUME - This subroutine is called by POINT and calculates the final plume rise.

RCONCP - This subroutine is called by POINT, HRZLN, CRVLN, SPCLN, and SPCCR. RCONCP calls PGSIG. RCONCP determines the relative concentration at a receptor from a point source at a given upwind and crosswind distance.

PGSIG - This subroutine is called by RCONCP and calculates σ_y and σ_z for a given stability and downwind distance.

RCONCA - This subroutine is called by AREA and calculates the relative concentration normalized for wind speed for a receptor downwind of a crosswind infinite line source.

CURLIN - This subroutine is called by CRVLN and SPCCR. CURLIN determines the coordinates of the intersection points, if any, of a curved path source and the line in the direction of the wind through the receptor coordinates.

XVY - This function is called by POINT, HRZLN, CRVLN, SPCLN and SPCCR. XVY calculates the virtual distance necessary to account for the initial crosswind dispersion.

XVZ - This function is called by POINT, HRZLN, CRVLN, SPCLN and SPCCR. XVZ calculates the virtual distance necessary to account for the initial vertical dispersion.

DIFANG - This function is called by CRVLN and SPCCR. DIFANG determines the angular difference between two angles.

ANGARC - This function is called by CRVLN and SPCCR. ANGARC determines the angle specified by a given slope. The resulting angle is between 0 and 360 degrees.

4. PREPARATION OF INPUT DATA

The sequence of input data cards is shown in Figure 3. The formats for the input data cards are shown in Table 1. All input data are in free format, except card 1 which is an alphanumeric 20A4 format. While the free format is very easy to use, care should be taken to make sure every variable is given a value in the correct order. Each variable should be separated by a comma. A complete description of the free format can be found in any Fortran reference manual. Integer variable names begin with the letters I - N. Those input cards which are optional are noted below the card type number. A brief description of each input parameter is given in Table 1 with the appropriate units. The metric system of units is used in PAL. Horizontal coordinates of sources are given in units of kilometers. Temperatures are given in units of degrees kelvin. Emission rates are given in mgs units (meter-gram-second).

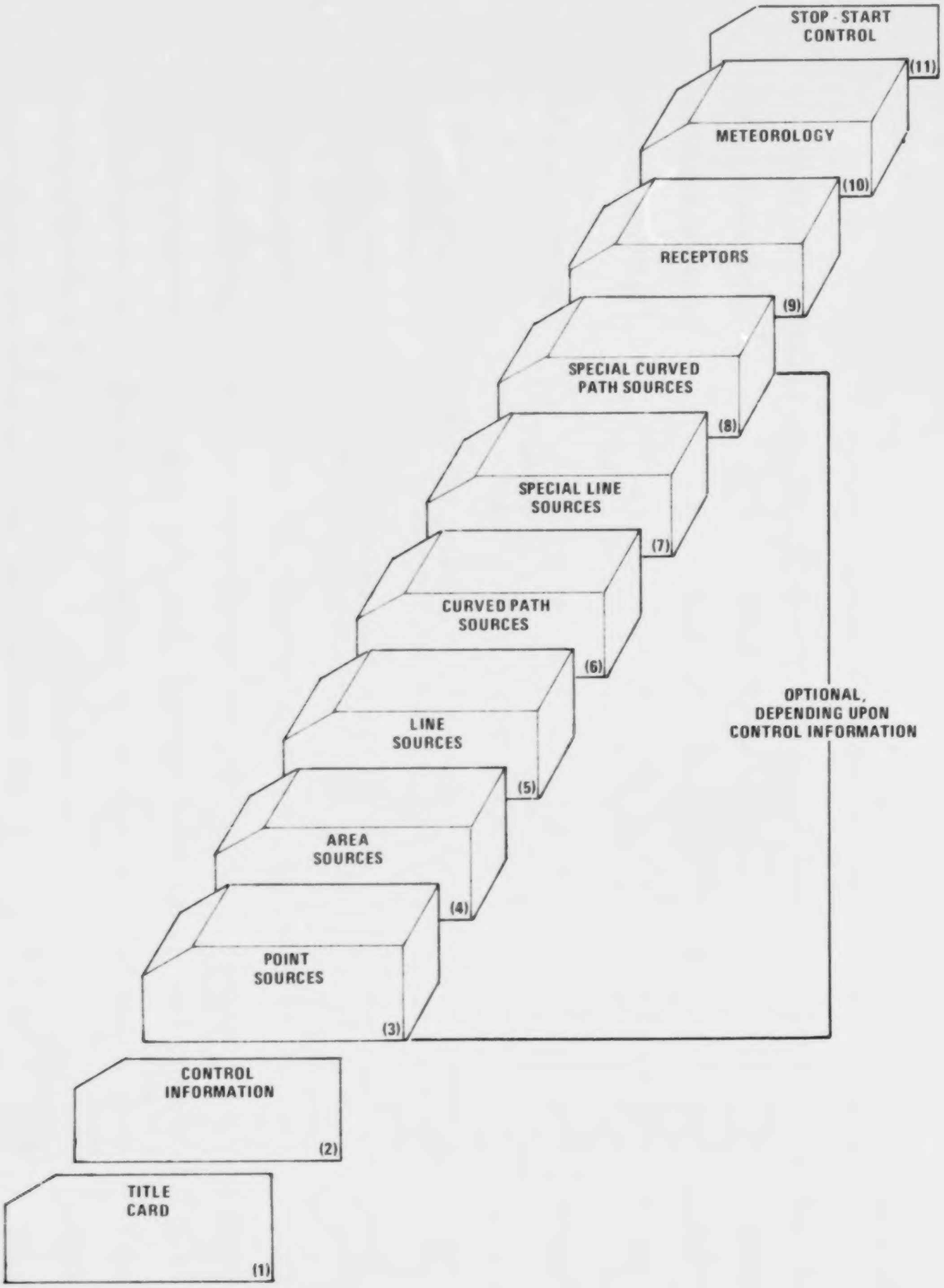
STOP - START CONTROL
(11)
METEOROLOGY
(10)
RECEPTORS
(9)
SPECIAL CURVED PATH SOURCES
(8)
SPECIAL LINE SOURCES
(7)
CURVED PATH SOURCES
(6)
LINE SOURCES
(5)
AREA SOURCES
(4)
POINT SOURCES
(3)
OPTIONAL, DEPENDING UPON CONTROL INFORMATION
CONTROL INFORMATION
(2)
TITLE CARD
(1)

Figure 3. Input data deck for the PAL model. Card type numbers are in parenthesis.

TABLE 1. DISCRIPTION OF INPUT DATA

CARD TYPE 1 20A4 FORMAT
ALPHANUMERIC TITLE TO IDENTIFY OUTPUT.

CARD TYPE 2 PINA,PINL,IQP,IUZP,IQA,IUZA,IQLH,IUZH,IQLC,IUZC,IQLS,IUZS,
IQAC,IUZE,IAVG,IDRNL,UHGT

PINA	TEST FOR AREA INTERGRATION ACCURACY. PINA IS IN DECIMAL FORM.	(DIMENSIONLESS)
PINL	TEST FOR LINE INTERGRATION ACCURACY. PINL IS IN DECIMAL FORM.	(DIMENSIONLESS)
IQP	CONTROL FOR POINT SOURCES. IF IQP=1,NO POINT SOURCES. IF IQP=2,UP TO 30 POINT SOURCES CAN BE INCLUDED.	(DIMENSIONLESS)
IUZP	WIND INCREASE WITH HEIGHT FOR POINT SOURCES. IF IUZP=1,NO CHANGE OF WIND SPEED WITH HEIGHT. IF IUZP=2,CHANGE OF WIND SPEED WITH HEIGHT IN EFFECT.	(DIMENSIONLESS)
IQA	CONTROL FOR AREA SOURCES. USED THE SAME AS IQP.	(DIMENSIONLESS)
IUZA	WIND INCREASE WITH HEIGHT FOR AREA SOURCES. USED THE SAME AS IUZP.	(DIMENSIONLESS)
IQLH	CONTROL FOR LINE SOURCES.USED THE SAME AS IQP.	(DIMENSIONLESS)
IUZH	WIND INCREASE WITH HEIGHT FOR HORIZONAL LINES. USED THE SAME AS IUZP.	(DIMENSIONLESS)
IQLC	CONTROL FOR CURVED PATH SOURCES.USED THE SAME AS IQP.	(DIMENSIONLESS)
IUZC	WIND INCREASE WITH HEIGHT FOR CURVED PATH SOURCES. USED THE SAME AS IUZP.	(DIMENSIONLESS)
IQLS	CONTROL FOR SLANT LINE SOURCES.USED THE SAME AS IQP.	(DIMENSIONLESS)
IUZS	WIND INCREASE WITH HEIGHT FOR SLANT LINE SOURCES. USED THE SAME AS IUZP.	(DIMENSIONLESS)
IQAC	CONTROL FOR SPECIAL PATH SOURCES. USED THE SAME AS IQP.	(DIMENSIONLESS)
IUZE	WIND INCREASE WITH HEIGHT FOR SPECIAL PATH SOURCES. USED THE SAME AS IUZP.	(DIMENSIONLESS)
IAVG	CONTROL FOR AVERAGE CONCENTRATIONS. IF IAVG=1, NO AVERAGES ARE CALCULATED. IF IAVG=2, AVERAGE CONCENTRATIONS CAN BE CALCULATED UP TO 24 HOURS.	(DIMENSIONLESS)

TABLE 1 (continued)

```
  IDRNL   CONTROL FOR EMISSION FACTORS. IF IDRNL=1, NO      (DIMENSIONLESS)
          HOURLY VARIATION IN EMISSIONS. IF IDRNL=2, HOURLY
          VARIATION IN EMISSIONS CAN BE INCLUDED.
  UHGT    THE HEIGHT APPLICABLE TO THE WIND MEASURMENT.      (M)

CARD TYPE 3     ICARD,QP,HPP,TSP,USP,DP,UFP,RQP,SQP,SYOP,SZOP
          CARD 3 IS OPTIONAL. (POINT SOURCES)
  ICARD   IF ICARD=1,MORE DATA CARDS ARE EXPECTED.           (DIMENSIONLESS)
          IF ICARD=2,LAST DATA CARD OF THIS TYPE.
  QP      POINT SOURCE STRENGTH.                             (G/SEC)
  HPP     PHYSICAL STACK HEIGHT.                             (M)
  TSP     STACK GAS TEMPERATURE.                             (DEG K)
  USP     STACK GAS VELOCITY. (USP IS DISREGARDED IF UFP     (M/SEC)
          IS GREATER THAN ZERO)
  DP      STACK INSIDE DIAMETER. (DP IS DISREGARDED IF UFP   (M)
          IS GREATER THAN ZERO)
  UFP     STACK GAS VOLUME FLOW.                             (M**3/SEC)
  RQP     EAST COORDINATE OF STACK.                          (KM)
  SQP     NORTH COORDINATE OF STACK.                         (KM)
  SYOP    INITIAL SIGMA Y.                                   (M)
  SZOP    INITIAL SIGMA Z.                                   (M)

CARD TYPE 4     ICARD,QA,HQ,RQ,SQ,DEST,DNOR,
          CARD 4 IS OPTIONAL. (AREA SOURCES)
  ICARD   USED THE SAME AS IN THE POINT SOURCES.             (DIMENSIONLESS)
  QA      AREA SOURCE STRENGTH.                              (G/SEC-M**2)
  HQ      AREA SOURCE HEIGHT.                                (M)
  RQ      EAST COORDINATE OF S.W. CORNER.                    (KM)
  SQ      NORTH COORDINATE OF S.W. CORNER.                   (KM)
  DEST    EAST-WEST SIZE.                                    (KM)
  DNOR    NORTH-SOUTH SIZE.                                  (KM)

CARD TYPE 5     ICARD,HLN,RAQ,SAQ,RBQ,SBQ,SYO,SZO,WT,WM,QLT
          CARD 5 IS OPTIONAL. (HORIZONAL LINE SOURCES)
  ICARD   USED THE SAME AS IN THE POINT SOURCES.             (DIMENSIONLESS)
  HLN     HEIGHT OF THE LINE SOURCE.                         (M)
  NL      NUMBER OF LANES.(1 LANE OR AN EVEN NUMBER OF LANES)(DIMENSIONLESS)
```

TABLE 1 (continued)

RAQ	EAST COORDINATE OF POINT A. (SEE FIGURE 4,	(KM)
SAQ	NORTH COORDINATE OF POINT A. APPENDIX A)	(KM)
RBQ	EAST COORDINATE OF POINT B.	(KM)
SBQ	NORTH COORDINATE OF POINT B.	(KM)
SYO	INITIAL SIGMA Y.	(M)
SZO	INITIAL SIGMA Z.	(M)
WT	TOTAL WIDTH OF LINE SOURCE.	(M)
WM	WIDTH OF THE MEDIAN.	(M)
QLT	LINE SOURCE EMISSION RATE, ONE FOR EACH LANE. ORDERING OF EMISSION RATES ARE FROM LEFT TO RIGHT WHEN LOOKING FROM POINT A TO POINT B.	(G/SEC-M)
CARD TYPE 6	ICARD,HLNS,NL,RBQS,SBQS,RMQS,SMQS,REQS,SEQS,SIYO,SIZO,WT,WM,QLTS CARD 6 IS OPTIONAL. (CURVED PATH SOURCES)	
ICARD	USED THE SAME AS IN THE POINT SOURCES.	(DIMENSIONLESS)
HLNS	HEIGHT OF CURVED PATH SOURCE.	(M)
NL	NUMBER OF LANES.(1 LANE OR AN EVEN NUMBER OF LANES)	(DIMENSIONLESS)
RBQS	EAST COORDINATE OF POINT A. (SEE FIGURE 5,	(KM)
SBQS	NORTH COORDINATE OF POINT A. APPENDIX A)	(KM)
RMQS	EAST COORDINATE OF POINT B.	(KM)
SMQS	NORTH COORDINATE OF POINT B.	(KM)
REQS	EAST COORDINATE OF POINT C.	(KM)
SEQS	NORTH COORDINATE OF POINT C.	(KM)
SIYO	INITIAL SIGMA Y.	(M)
SIZO	INITIAL SIGMA Z.	(M)
WT	TOTAL WIDTH OF PATH SOURCE.	(M)
QLTS	CURVED PATH SOURCE EMISSION RATE,ONE FOR EACH LANE. ORDERING OF EMISSION RATES ARE FROM OUTSIDE LANE TO INSIDE.	(G/SEC-M)
CARD TYPE 7	ICARD,QLS,HAS,HBS,RAS,SAS,RBS,SBS,SPDI,SPDF,SYOS,SZOS,TVSL,VSSL CARD 7 IS OPTIONAL.(SPECIAL LINE SOURCES)	
ICARD	USED THE SAME AS IN THE POINT SOURCES.	(DIMENSIONLESS)
QLS	LINE SOURCE STRENGTH, ONE LANE ONLY.	(G/SEC)
HAS	HEIGHT OF POINT A.	(M)
HBS	HEIGHT OF POINT B.	(M)
RAS	EAST COORDINATE OF POINT A.	(KM)

TABLE 1 (continued)

```
  SAS     NORTH COORDINATE OF POINT A.                         (KM)
  RBS     EAST COORDINATE OF POINT B.                          (KM)
  SBS     NORTH COORDINATE OF POINT B.                         (KM)
  SPDI    VEHICLE SPEED AT POINT A.                            (M/SEC)
  SPDF    VEHICLE SPEED AT POINT B.                            (M/SEC)
  SYOS    INITIAL SIGMA Y.                                     (M)
  SZOS    INITIAL SIGMA Z.                                     (M)
  TVSL    VEHICLE VOLUME.                                      (VEH/HR)
  VSSL    GROSS ESTIMATE OF VEHICLE SIZE.                      (M)

CARD TYPE 8    ICARD,QLNA,HCL,RBQA,SBQA,RMQA,SMQA,REQA,SEQA,SPEI,SPEF,SIYA,SIZA
          TVCL,VSCL
          CARD 8 IS OPTIONAL.(SPECIAL CURVED PATH SOURCES)
  ICARD   USED THE SAME AS IN THE POINT SOURCES.               (DIMENSIONLESS)
  QLNA    PATH SOURCE STRENGTH,ONE LANE ONLY.                  (G/SEC)
  HCL     PATH SOURCE HEIGHT.                                  (M)
  RBQA    EAST COORDINATE OF POINT A.                          (KM)
  SBQA    NORTH COORDINATE OF POINT A.                         (KM)
  RMQA    EAST COORDINATE OF POINT B.                          (KM)
  SMQA    NORTH COORDINATE OF POINT B.                         (KM)
  REQA    EAST COORDINATE OF POINT C.                          (KM)
  SEQA    NORTH COORDINATE OF POINT C.                         (KM)
  SPEI    VEHICLE SPEED AT POINT A.                            (M/SEC)
  SPEF    VEHICLE SPEED AT POINT C.                            (M/SEC)
  SIYA    INITIAL SIGMA Y.                                     (M)
  SIZA    INITIAL SIGMA Z.                                     (M)
  TVCL    VEHICLE VOLUME.                                      (VEH/HR)
  VSCL    GROSS ESTIMATE OF VEHICLE SIZE.                      (M)

CARD TYPE 9    ICARD,RR,SR,ZR
  ICARD   USED THE SAME AS IN THE POINT SOURCES.               (DIMENSIONLESS)
  RR      EAST COORDINATE OF RECEPTOR.                         (KM)
  SR      NORTH COORDINATE OF RECEPTOR.                        (KM)
  ZR      HEIGHT OF RECEPTOR.                                  (M)

CARD TYPE 10   ICARD,UTHET,WU,MKST,WHL,WTA,DVP,DVA,DVH,DVS,DDVH,DVHA
  ICARD   USED THE SAME AS IN THE POINT SOURCES.UP TO 24       (DIMENSIONLESS)
```

TABLE 1 (continued)

	HOURS OF METEOROLOGY CAN BE INPUT.	
WTHET	WIND DIRECTION.	(DEG AZIMUTH)
WU	WIND SPEED.	(M/SEC)
MKST	STABILITY CLASS.	(DIMENSIONLESS)
WHL	MIXING HEIGHT.	(M)
WTA	AMBIENT AIR SURFACE TEMPERATURE.	(DEG K)
DVP	HOURLY VARIATION OF EMISSIONS FOR POINT SOURCES.	(DIMENSIONLESS)
DVA	HOURLY VARIATION OF EMISSIONS FOR AREA SOURCES.	(DIMENSIONLESS)
DVH	HOURLY VARIATION OF EMISSIONS FOR LINE SOURCES.	(DIMENSIONLESS)
DVS	HOURLY VARIATION OF EMISSIONS FOR SPECIAL LINE SOURCES.	(DIMENSIONLESS)
DDVH	HOURLY VARIATION OF EMISSIONS FOR CURVED PATH SOURCES.	(DIMENSIONLESS)
DVHA	HOURLY VARIATION OF EMISSIONS FOR SPECIAL PATH SOURCES.	(DIMENSIONLESS)
	IF IDRNL=1,(CARD 2) NO HOURLY INFORMATION NEEDED. IF IDRNL=2, THE HOURLY VARIATION OF EMISSIONS ARE GIVEN AS THE RATIO OF THAT EMITTED DURING THIS HOUR TO THE INPUT EMISSION. IF THE SAME AS THE INPUT,THE VALUE IS 1.00.	
CARD TYPE 11	KTL	
KTL	IF KTL=0 PROGRAM TERMINATES. IF KTL=1, START NEW PROBLEM. IF KTL=2,READ NEW RECEPTOR AND METEOROLOGY DATA. IF KTL=3,READ NEW METEOROLOGY DATA.	(DIMENSIONLESS)

Table 1 should be helpful in organizing data for input into PAL. However, there are several variables that may need further explanation. The balance of this section will be concerned with explaining the use of these input variables and should aid the user in assigning values to them.

POINT SOURCES

In the point source subroutine (POINT) the stack gas velocity (VSP) and stack inside diameter (DP) are ignored if the stack gas volume flow (VFP) is greater than zero. However, VSP and DP must still be specified with dummy values since the free format requires values for all variables. If there are no point sources in a particular run, then the ambient air temperature (WTA) from the meteorology input card type 10 is ignored. If WTA equals zero, then a value of 293^{o}K is assumed in the program.

In subroutine POINT the initial dispersion parameters SYOP and SZOP allow for initial dispersion in the horizontal and vertical, respectively. For a tall stack these parameters would generally have little influence on downwind concentrations. The initial dispersion parameters would be helpful in accounting for the initial mixing of a plume in the building wake. Due to the complex turbulence in the building wake, plume dispersion is best modeled using physical models. However, there are some simple cases where the initial dispersion parameters would be applicable. The values suggested for SYOP and SZOP in this report should be considered preliminary in nature. It is beyond the scope of this report to undertake a detailed discussion of aerodynamic effects in the wake of a building. Some pertinent points are discussed below concerning the circumstances in which aerodynamic effects are a problem and where SYOP and SZOP might be useful.

For a squat building, whose width is $\geq$ its height, a sufficient stack height and exit velocity for the effluent to escape the influence of the building is given by the familiar 2½ times rule. The rule simply states that if the stack height is greater than 2½ h (where h is the building height) and the exit velocity of the plume is greater than 1.5 $\bar{u}$ (where $\bar{u}$ is the mean wind speed), then the plume will escape from the influence of the building. Stack height always refers to the height of the stack above the ground. For a tall building, whose height is greater than its width, the 2½ rule can be relaxed. Briggs (1973) suggested that a sufficient stack height would be the building height plus 1.5 ℓ (where ℓ is the smaller of either the building height, or the maximum width of the building perpendicular to the wind direction). If the criteria in either one of the above rules are met, then the stack can be considered a tall one, and building influences may be ignored.

In a recent wind tunnel study, for a squat building, whose width was twice its height, Huber and Snyder (1976) suggested that the plume was strongly affected by the recirculating flow in the wake "cavity" region behind the building during the following conditions: (1) When the stack height was $\leq$ 1.2 h and (2) When the exit velocity was $\leq$ 1.5 $\bar{u}$. The buoyancy of the plume is generally not a factor in the initial plume capture within the "cavity" region. If the above criteria are met, then SYOP and SZOP can be used to model the initial mixing. Huber (Communication, May 1977) suggests that appropriate initial dispersion parameters might be

$$\sigma_{yo} = 0.35\ H_b \simeq \frac{1.5\ H_b}{4.3}$$

$$\sigma_{zo} = 0.7\ h \approx \frac{1.5\ h}{2.15}$$

where: H_b is the width of the building and h is the building height.

These findings are applicable for cubical or squat buildings. For a building much wider than it is tall, it would be expected that σ_{yo} would reach a maximum. Concentrations very close to the building are extremely sensitive to the shape and orientation of the building with respect to the location of the source. Concentration estimates using the above initial dispersion parameters are more likely applicable for distances beyond ten building heights downwind. The last case that remains is a most difficult one: either the stack is not tall enough or the exit velocity of the plume not great enough for the plume to escape the influence of the building, but the plume is not totally affected by the building wake. The plume may be totally or partially captured in the displacement zone where it may be brought near the ground at some distance downwind. In such cases, physical models should be used to examine plume dispersion. More research is needed to determine the extent of the displacement zone and cavity behind a variety of shapes of buildings. The above initial dispersion parameters are intended to provide some guidance until more complete analyses can be obtained.

AREA SOURCES

It is not mandatory that variables DEST and DNOR on card type 4 have the same dimensions. Area sources can be either squares or rectangles. A special feature in PAL allows for the area source strength to be negative. The advantage of this feature is demonstrated in the example problem in Section 5.

LINE SOURCES

In all of the line and curved path source subroutines the height of emissions must be specified. In the past there has been some confusion with this parameter in the EPA HIWAY model. The variables HLN, HLNS, and HCL on card types 5, 6, and 8, respectively, represent the height of the line or curved path above the surrounding terrain. For a highway it is not the height of the highway above the surrounding terrain, but the height of the emissions above the highway. It is assumed that the height of the highway and surrounding terrain are nearly the same.

A uniform emission rate, q_ℓ, must be specified for each line source in subroutines HRZLN and CRVLN. For vehicles this line-source emission rate can be found if the emission factor, EF(g veh^{-1} mi^{-1}), and the traffic volume, TV(veh hr^{-1}), are known.

$$q_\ell \ (\text{g sec}^{-1}\ \text{m}^{-1}) = \frac{\text{EF(g veh mi}^{-1})\ \text{TV(veh hr}^{-1})}{1609.3\ (\text{m mi}^{-1})\ 3600\ (\text{sec hr}^{-1})}$$

$$= 1.726 \times 10^{-7}\ (\text{EF})\ (\text{TV})$$

A value of the emission factor for automobiles can be obtained from supplement No. 5 for Compilation of Air Pollutant Emission Factors (EPA 1975). If the special line or special path sources are used, both of which allow the emission rate to vary, the user must specify the traffic volume (veh hr^{-1}) and the emission factor (g sec^{-1}) since these parameters are used internally to derive the variable emission rate as a function of location along the source. The reader should note that due to changes in the computer code, the emission factors for special sources have different units than the emission factors, as described in Appendix A. The emission factors for aircraft, where traffic volumes are low, should be 1-hour average values. PAL is not intended to predict peak concentrations that are likely to occur from aircraft emissions but rather is intended to estimate the average concentration over a 1-hour time period. The variables VSSL and VSCL on card types 7 and 8, respectively, are a rough estimate of the length of the vehicles being considered. The function of these parameters is discussed in Part 2 of Appendix A.

METEOROLOGY

The stability of the atmosphere (MKST) is specified on card type 10. The atmospheric stability is used to estimate the horizontal and vertical dispersion parameters, σ_y, σ_z. The dispersion parameters were developed from data most applicable to open country (Pasquill, 1961). When PAL is used in urban areas the stability parameters can be modified slightly to account for the increase in the roughness elements and the generally more unstable air over urban environments. Busse and Zimmerman (1973) employed a simple technique in the Climatological Dispersion Model to account for the increase in dispersion. This technique was summarized by Turner (1976). Table 2 shows the stability for open country and the recommended stability for point and area sources in urban areas.

TABLE 2. STABILITY CLASSIFICATION

Open Country Stability	Equivalent Stability for Urban Area	
	Area Sources	Point Sources
A	A	A
B	A	B
C	B	C
D (day)	C	D
D (night)	D	D
E and F	D	D

Other techniques have been developed for characterizing the dispersion in urban areas. Smith (1972) developed a technique for estimating the dispersion parameters based on a continuous stability parameter, which incorporates effects of roughness. Weber (1976) has reviewed current systems for estimating atmospheric dispersion parameters in Gaussian plume models. PAL is constructed so that improved techniques to estimate dispersion parameters, can be incorporated in it as development in this area continues.

The wind-increase-with-height option allows the user to either specify the wind speed (constant for all heights) or to use the option and let the program estimate the wind speed for different heights. To account for an increase of wind with height a power law of the form

$$u_{(z)} = u_o \left(\frac{z}{z_o}\right)^p$$

is used in PAL. Irwin (1977) suggested a theoretical variation of the wind profile power-law exponent as a function of surface roughness and stability.

The exponents given in Table 3 are appropriate for a surface roughness typical of urban areas.

TABLE 3. EXPONENTS FOR WIND PROFILE

Stability class	Exponent (p)
A	0.15
B	0.15
C	0.20
D	0.25
E	0.40
F	0.60

On card type 2 of the input data, UHGT is the height applicable to the wind speed, generally anemometer height. This variable is only used if the wind increase with height option is used for one or more of the source types. However, if the option is not used, a value for UHGT is required due to the free format input. The usual anemometer height for airport data is in the range of 7-10 meters.

If the wind-increase-with-height option is used with sources near the ground, the wind speed will be estimated at the source height but will not be allowed to go below 1.0 m $\sec^{-1}$. An increase of wind speed with height is calculated up to 200 meters. Above this height the wind speed is assumed to remain constant.

5. EXAMPLE PROBLEM

An example problem is provided to demonstrate the use of PAL. The sources are shown in Figure 4: one point source, two area sources, three line sources, one curved path source, and two special line sources. This example is intended to be a simplified model of an airport; none of the emissions and physical dimensions should be considered realistic. Also, not all of the sources of emissions, such as taxiways, are included in this example problem. Notice that the two area sources are overlayed. In this particular example the hatched area represents a building with no emissions and the other area source is a parking lot with its associated emissions. The area source strength for the building is the same as that for the parking lot but negative in sign (see Table 4). The effect of the negative area source strength is to make the concentration from the building equal to zero. Also, using the negative area source strength reduces the number of area source inputs from three to two in this case. The point source is an incinerator. Line sources one and two are fourlane highways with a fourlane curved path source in between. Line source three is a twolane entrance road. The special line sources are active runways.

Table 4 shows the input data cards for this example. The numbers in the left hand column are the input card type numbers. For a description of each input card type see Table 1. In this example there is no input card type 8, since there are no special curved path sources. Input data cards for source types, receptor locations, and hourly meteorology have, as a first variable, an integer called ICARD. If ICARD equals one, more cards of this type are expected. If ICARD equals two, then the last card of this type is expected. At card type 11 the program will terminate if KTL = 0 (see Table 1). Three other options are also available:

- To start a new problem giving all the input information.
- To leave all sources the same but input new information on receptors and meteorology.
- To input new information on meteorology.

Table 5 is a computer listing of the output for the example problem. The output begins with a listing of all input parameters and options used. PINA and PINL are the area and line source integration accuracies. Sources included are indicated by "YES's" under the column titled "Source Included." In the second column headed "Wind Increase With Height," the "NO's" mean that the option of having the wind increase with height is not used for any of the sources. Average concentrations are calculated based on the number of hours of meteorology (card type 10). In this example two 3-hour average concentrations are calculated for each source type. The hourly variation in emissions option is not used. Next, the source input data are listed in the print-out. Following the source information are the receptor coordinates for each receptor. The meteorological data are printed out to conclude the listing of input. The "Concentration At Receptors" for each source type, g m^{-3}, and a total concentration for all types are then printed. Finally the 3-hour average concentrations for each source type are printed out for each set of meteorology. Average concentration estimates are indicated by zeros in the column entitled "Hour."

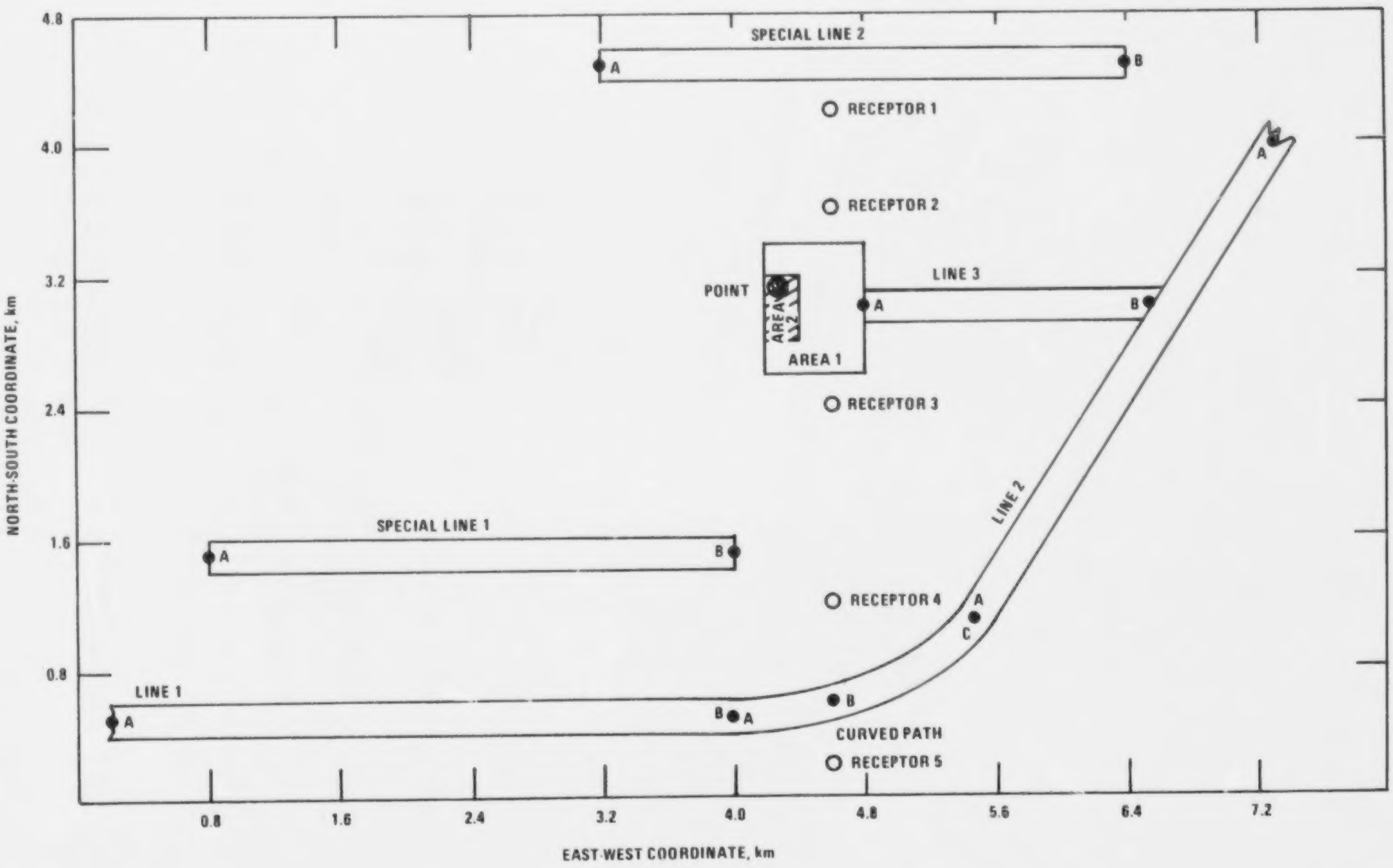
SPECIAL LINE 2
A
B
RECEPTOR 1
RECEPTOR 2
POINT
AREA 2
AREA 1
LINE 3
A
B
RECEPTOR 3
SPECIAL LINE 1
A
B
RECEPTOR 4
LINE 2
A
C
A
LINE 1
A
B
A
B
CURVED PATH
RECEPTOR 5
4.8
4.0
3.2
2.4
1.6
0.8
NORTH-SOUTH COORDINATE, km
0.8
1.6
2.4
3.2
4.0
4.8
5.6
6.4
7.2
EAST-WEST COORDINATE, km

Figure 4. Source types included in example problem.

TABLE 4. INPUT DATA FOR EXAMPLE PROBLEM

```
CARD
TYPE
  1     EXAMPLE PROBLEM FOR PAL
  2     0.02,0.02,2,1,2,1,2,1,2,1,2,1,1,1,2,1,5.
  3     2,5.0,10.0,320.,0.,0.,12.,4.26,3.14,1.,1.
  4     1,0.0002,0.,4.2,2.6,0.6,0.8
  4     2,-0.0002,0.,4.2,2.8,0.2,0.4
  5     1,0.,4,0.2,0.5,4.0,0.5,3.0,1.5,16.,0.,0.001,0.002,0.0009,0.001
  5     1,0.,4,5.45,1.3,7.3,4.,3.,1.5,16.,0.,0.0018,0.0018,0.0009,0.0007
  5     2,0.,2,4.8,3.,6.52,3.,3.,1.5,8.,0.,0.002,0.002
  6     2,0.,4,4.,0.5,4.6,0.58,5.45,1.3,3.,1.5,16.,0.,0.001,0.002,0.0009,0.001
  7     1,30.,3.,3.,3.2,4.5,6.4,4.5,0.,80.,15.,6.,60.,30.
  7     2,10.,3.,3.,0.8,1.5,4.,1.5,80.,0.,15.,6.,60.,30.
  9     1,4.6,4.2,1.
  9     1,4.6,3.6,1.
  9     1,4.6,2.4,1.
  9     1,4.6,1.2,1.
  9     2,4.6,0.2,1.
 10     1,0.,2.,4,500.,285.
 10     1,350.,2.5,3,900.,289.
 10     2,345.,3.,2,1100.,294.
 11     3
 10     1,30.,3.,4,1000.,290.
 10     1,45.,6.1,4,1000.,300.
 10     2,50.,3.8,3,1000.,298.
 11     0
```

TABLE 5. COMPUTER OUTPUT FOR EXAMPLE PROBLEM

```
                                                                                      VERSION 78001
EXAMPLE PROBLEM FOR PAL
PINA =    .02000 PINL =    .02000
               SOURCE     WIND INCREASE
              INCLUDED    WITH  HEIGHT

    POINT        YES             NO

    AREA         YES             NO

HORIZONTAL
LINE SOURCE      YES             NO

    CURVE
PATH SOURCE      YES             NO

  SPECIAL
LINE SOURCE      YES             NO

  SPECIAL
PATH SOURCE      NO              NO          AVERAGE     YES   DIURNAL    NO     HEIGHT AT WIND SPEED    5.0 METERS

* * * P O I N T   S O U R C E S * * *
     NO.     POINT     PHYSICAL    STACK      STACK      STACK      VOLUME        COORDINATES          INITIAL SIGMAS
             SOURCE     HEIGHT     TEMP        GAS      DIAMETER     FLOW        EAST     NORTH           Y          Z
            STRENGTH   (METERS)   (DEG-K)   VELOCITY   (METERS)  (CU M/SEC)     (KM)      (KM)           (M)        (M)
             (G/SEC)                         (M/SEC)

      1        5.00       10.0     320.0        .00        .00      12.00       4.260     3.140          1.0        1.0


 * * A R E A   S O U R C E S * * *
     NO.     AREA        AREA         COORDINATES          AREA SIZE
            SOURCE      SOURCE         SW-CORNER
           STRENGTH     HEIGHT      EAST      NORTH   EAST-WEST NORTH-SOUTH
         (G/SEC-M**2)  (METERS)     (KM)      (KM)      (KM)       (KM)

      1   .00020000        .0      4.200     2.600      .600       .800
      2  -.00020000        .0      4.200     2.800      .200       .400


 * * H O R I Z O N T A L   L I N E   S O U R C E S * * *
     NO.     LINE        LINE                     COORDINATES
            SOURCE      SOURCE          POINT A               POINT B             INITIAL SIGMAS                  NO.     TOTAL     MEDIAN
           STRENGTH     HEIGHT      EAST      NORTH       EAST      NORTH           Y          Z                  OF      WIDTH      WIDTH
           (G/SEC-M)   (METERS)     (KM)      (KM)        (KM)      (KM)           (M)        (M)               LANES  (METERS)  (METERS)
                                                                                                                   4.      16.0        .0
      1   .00100000        .0       .200      .506       4.000      .506          3.00       1.50
      2   .00200000        .0       .200      .502       4.000      .502          3.00       1.50
      3   .00090000        .0       .200      .498       4.000      .498          3.00       1.50
      4   .00100000        .0       .200      .494       4.000      .494          3.00       1.50             4.      16.0        .0

      5   .00180000        .0      5.445     1.303       7.295     4.003          3.00       1.50
      6   .00180000        .0      5.448     1.301       7.298     4.001          3.00       1.50
      7   .00090000        .0      5.452     1.299       7.302     3.999          3.00       1.50
      8   .00070000        .0      5.455     1.297       7.305     3.997          3.00       1.50             2.       8.0        .0

      9   .00200000        .0      4.800     3.002       6.520     3.002          3.00       1.50
     10   .00200000        .0      4.800     2.998       6.520     2.998          3.00       1.50
```

TABLE 5 (continued)

```
**CURVED HORIZONAL PATH SOURCES***
NO.    PATH        PATH              COORDINATES
      SOURCE      SOURCE      POINT A              POINT B            POINT C          INITIAL SIGMAS       NO.    TOTAL     MEDIAN
     STRENGTH     HEIGHT   EAST     NORTH       EAST      NORTH     EAST      NORTH       Y          Z          OF     WIDTH     WIDTH
    (G/SEC-M)   (METERS)  (KM)      (KM)        (KM)      (KM)      (KM)      (KM)       (M)        (M)       LANES  (METERS)  (METERS)

 1   .00100000     .000   4.000      .500       4.000      .500     5.450     1.300     3.00       1.50        4      16.00       .00

        SOURCE STRENGTH FOR THE REMAINING LANES
            LANE      SOURCE STRENGTH

              2         .00200000
              3         .00000000
              4         .00100000


***SLANT OR VERTICAL LINE SOURCES***
   NO.    SOURCE       SOURCE HEIGHT              POINT A              POINT B            INITIAL   FINAL    INITIAL SIGMAS  TRAFFIC VEH.
        STRENGTH        (METERS)          EAST      NORTH      EAST      NORTH       SPEED     SPEED      Y       Z     VOLUME   SIZE
         (G/SEC)    POINT A   POINT B     (KM)      (KM)       (KM)      (KM)      (M/SEC)   (M/SEC)    (M)     (M)   (VEH/HR) (M)

    1     30.00       3.0       3.0      3.200     4.500      6.400     4.500        .000    80.000    15.00   6.00     80.   30.0
    2     10.00       3.0       3.0       .800     1.500      4.000     1.500      80.000      .000    15.00   6.00     80.   30.0


***RECEPTORS***
   NO.    RREC(KM)  SREC(KM)    Z (M)

    1      4.600     4.200      1.0
    2      4.600     3.600      1.0
    3      4.600     2.400      1.0
    4      4.600     1.200      1.0
    5      4.600      .200      1.0


***METEOROLOGY***
   NO.  THETA(DEG)   U (M/SEC)    KST   HL (M)  T (DEG-K)        DIURNAL VARIATIONS (FRACTIONS OF GIVEN Q)
                                                                                    HORIZONAL  CURVED   SPECIAL   SPECIAL
                                                                  POINT     AREA      LINE      PATH      LINE      PATH
   1.        0.        2.0          4     500.     285.          1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
   2.      350.        2.5          3     900.     290.          1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
   3.      345.        3.0          2    1100.     294.          1.0000    1.0000    1.0000    1.0000    1.0000    1.0000


***CONCENTRATIONS AT RECEPTORS***
   CONCENTRATIONS IN GRAMS PER CUBIC METER                       FROM        FROM       FROM       FROM
HOUR RECEPTOR    RECEPTOR COORDINATES     FROM        FROM        HORIZONAL   CURVED     SPECIAL    SPECIAL
       NO.      EAST     NORTH   HEIGHT   POINTS      AREAS       LINES       PATHS      LINES      PATHS        TOTAL


 1     1        4.600    4.200   1.00     0.000       0.000       0.000       0.000      2.288-04   0.000        2.288-04
 1     2        4.600    3.600   1.00     0.000       0.000       0.000       0.000      1.145-04   0.000        1.145-04
 1     3        4.600    2.400   1.00     1.833-13    3.468-03    3.179-10    0.000      7.017-05   0.000        3.538-03
 1     4        4.600    1.200   1.00     2.274-08    1.290-03    1.530-08    0.000      5.379-05   0.000        1.344-03
 1     5        4.600     .200   1.00     9.873-08    8.384-04    3.244-08    1.338-04   4.636-05   0.000        1.085-03
```

TABLE 5 (continued)

```
* *C O N C E N T R A T I O N S   A T    R E C E P T O R S* * *
    CONCENTRATIONS IN GRAMS PER CUBIC METER                           FROM       FROM       FROM       FROM
HOUR RECEPTOR     RECEPTOR COORDINATES    FROM       FROM       HORIZONAL  CURVED     SPECIAL    SPECIAL
        NO.       EAST     NORTH   HEIGHT  POINTS     AREAS      LINES      PATHS      LINES      PATHS      TOTAL

  2     1        4.600    4.200    1.00    0.000      0.000      0.000      0.000      1.218-04   0.000      1.218-04
  2     2        4.600    3.600    1.00    0.000      0.000      0.000      0.000      5.366-05   0.000      5.366-05
  2     3        4.600    2.400    1.00    5.868-06   1.510-03   2.320-11   0.000      2.887-05   0.000      1.545-03
  2     4        4.600    1.200    1.00    2.797-06   2.387-04   1.882-08   0.000      2.336-05   0.000      2.900-04
  2     5        4.600     .200    1.00    1.119-06   8.272-05   3.242-08   6.214-06   2.203-05   0.000      1.781-04

* *C O N C E N T R A T I O N S   A T    R E C E P T O R S* * *
    CONCENTRATIONS IN GRAMS PER CUBIC METER                           FROM       FROM       FROM       FROM
HOUR RECEPTOR     RECEPTOR COORDINATES    FROM       FROM       HORIZONAL  CURVED     SPECIAL    SPECIAL
        NO.       EAST     NORTH   HEIGHT  POINTS     AREAS      LINES      PATHS      LINES      PATHS      TOTAL

  3     1        4.600    4.200    1.00    0.000      0.000      0.000      0.000      7.320-05   0.000      7.320-05
  3     2        4.600    3.600    1.00    0.000      0.000      0.000      0.000      2.682-05   0.000      2.682-05
  3     3        4.600    2.400    1.00    2.570-06   7.042-04   7.555-10   0.000      1.400-05   0.000      7.440-04
  3     4        4.600    1.200    1.00    6.731-06   5.882-05   2.003-08   0.000      1.017-05   0.000      7.574-05
  3     5        4.600     .200    1.00    2.070-06   1.713-05   2.041-08   3.483-05   1.081-05   0.000      6.486-05
AVERAGE CONCENTRATIONS FOR   3 HOURS.

* *C O N C E N T R A T I O N S   A T    R E C E P T O R S* * *
    CONCENTRATIONS IN GRAMS PER CUBIC METER                           FROM       FROM       FROM       FROM
HOUR RECEPTOR     RECEPTOR COORDINATES    FROM       FROM       HORIZONAL  CURVED     SPECIAL    SPECIAL
        NO.       EAST     NORTH   HEIGHT  POINTS     AREAS      LINES      PATHS      LINES      PATHS      TOTAL

  0     1        4.600    4.200    1.00    0.000      0.000      0.000      0.000      1.406-04   0.000      1.406-04
  0     2        4.600    3.600    1.00    0.000      0.000      0.000      0.000      6.501-05   0.000      6.501-05
  0     3        4.600    2.400    1.00    1.052-05   1.890-03   3.655-10   0.000      3.771-05   0.000      1.938-03
  0     4        4.600    1.200    1.00    1.238-05   5.279-04   5.281-07   0.000      2.911-05   0.000      5.699-04
  0     5        4.600     .200    1.00    7.643-06   3.107-04   1.000-06   7.806-05   2.640-05   0.000      4.227-04

* *M E T E O R O L O G Y* * *
     NO.  THETA(DEG)    U (M/SEC)    KST   HL (M)  T (DEG-K)          DIURNAL VARIATIONS (FRACTIONS OF GIVEN Q)
                                                                                           HORIZONAL  CURVED   SPECIAL   SPECIAL
                                                                      POINT     AREA       LINE       PATH     LINE      PATH
     1.       30.          3.0        4    1000.      290.            1.0000    1.0000     1.0000     1.0000   1.0000    1.0000
     2.       45.          6.1        4    1000.      300.            1.0000    1.0000     1.0000     1.0000   1.0000    1.0000
     3.       60.          3.8        3    1000.      290.            1.0000    1.0000     1.0000     1.0000   1.0000    1.0000

* *C O N C E N T R A T I O N S   A T    R E C E P T O R S* * *
    CONCENTRATIONS IN GRAMS PER CUBIC METER                           FROM       FROM       FROM       FROM
HOUR RECEPTOR     RECEPTOR COORDINATES    FROM       FROM       HORIZONAL  CURVED     SPECIAL    SPECIAL
        NO.       EAST     NORTH   HEIGHT  POINTS     AREAS      LINES      PATHS      LINES      PATHS      TOTAL

  1     1        4.000    4.000    1.00    0.000      0.000      0.000      0.000      1.523-04   0.000      1.523-04
  1     2        4.000    3.000    1.00    0.000      0.000      0.000      0.000      6.946-06   0.000      6.946-06
```

TABLE 5 (continued)

```
  1    3      4.600    2.400    1.00      0.000      7.377-04  4.984-05  0.000     3.602-05  0.000      8.235-04
  1    4      4.600    1.200    1.00      0.000      0.000     2.370-05  0.000     8.943-06  0.000      3.264-05
  1    5      4.600     .200    1.00      0.000      0.000     5.631-05  1.355-04  3.918-07  0.000      1.922-04

 * * C O N C E N T R A T I O N S   A T    R E C E P T O R S * * *
    CONCENTRATIONS IN GRAMS PER CUBIC METER                        FROM      FROM       FROM      FROM
HOUR RECEPTOR     RECEPTOR COORDINATES    FROM       FROM      HORIZONAL CURVED     SPECIAL   SPECIAL
       NO.      EAST    NORTH   HEIGHT   POINTS     AREAS     LINES     PATHS      LINES      PATHS      TOTAL

  2    1      4.600    4.200    1.00      0.000      0.000     0.000     0.000     7.834-05  0.000      7.834-05
  2    2      4.600    3.600    1.00      0.000      0.000     0.000     0.000     3.398-05  0.000      3.398-05
  2    3      4.600    2.400    1.00      0.000      3.868-05  2.567-05  0.000     2.113-06  0.000      6.646-05
  2    4      4.600    1.200    1.00      0.000      0.000     3.911-05  0.000     2.202-11  0.000      3.911-05
  2    5      4.600     .200    1.00      0.000      0.000     6.330-06  1.565-05  1.743-16  0.000      2.198-05

 * * C O N C E N T R A T I O N S   A T    R E C E P T O R S * * *
    CONCENTRATIONS IN GRAMS PER CUBIC METER                        FROM      FROM       FROM      FROM
HOUR RECEPTOR     RECEPTOR COORDINATES    FROM       FROM      HORIZONAL CURVED     SPECIAL   SPECIAL
       NO.      EAST    NORTH   HEIGHT   POINTS     AREAS     LINES     PATHS      LINES      PATHS      TOTAL

  3    1      4.600    4.200    1.00      0.000      0.000     6.466-29  0.000     7.794-05  0.000      7.794-05
  3    2      4.600    3.600    1.00      0.000      0.000     8.700-16  0.000     2.625-05  0.000      2.625-05
  3    3      4.600    2.400    1.00      0.000      1.797-05  2.299-05  0.000     5.130-07  0.000      4.147-05
  3    4      4.600    1.200    1.00      0.000      0.000     2.836-05  2.164-14  1.268-10  0.000      2.836-05
  3    5      4.600     .200    1.00      0.000      0.000     2.064-06  5.640-06  7.068-14  0.000      7.702-06
AVERAGE CONCENTRATIONS FOR   3 HOURS.

 * * C O N C E N T R A T I O N S   A T    R E C E P T O R S * * *
    CONCENTRATIONS IN GRAMS PER CUBIC METER                        FROM      FROM       FROM      FROM
HOUR RECEPTOR     RECEPTOR COORDINATES    FROM       FROM      HORIZONAL CURVED     SPECIAL   SPECIAL
       NO.      EAST    NORTH   HEIGHT   POINTS     AREAS     LINES     PATHS      LINES      PATHS      TOTAL

  0    1      4.600    4.200    1.00      0.000      0.000     2.155-29  0.000     1.029-04  0.000      1.029-04
  0    2      4.600    3.600    1.00      0.000      0.000     2.900-16  0.000     4.383-05  0.000      4.383-05
  0    3      4.600    2.400    1.00      0.000      2.648-04  3.283-05  0.000     1.288-05  0.000      3.105-04
  0    4      4.600    1.200    1.00      0.000      0.000     3.039-05  7.215-15  2.981-06  0.000      3.337-05
  0    5      4.600     .200    1.00      0.000      0.000     2.157-05  5.225-05  1.306-07  0.000      7.396-05
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APPENDIX A

TECHNICAL DESCRIPTION OF PAL

The technical description of PAL is covered in two parts. Part 1 consists of a reprint from the Proceedings of the Sixth International Technical Meeting on Air Pollution Modeling and its application held 24-26 September, 1975. The paper appears in the NATO Committee on the Challenges of Modern Society, Series on Air Pollution, Volume 42. The reader will notice that there have been minor revisions in the format of the input and output of the model since the 1975 paper. However, the following technical description of the basis and formulation of the model is accurate.

Part 2 of Appendix A describes the mathematical formulation for the special line and special curved path sources. This section was not presented previously and is given here for completeness.

6th NATO/CCMS
International Technical Meeting
on Air Pollution Modeling

APM 6 / 1

A GAUSSIAN-PLUME ALGORITHM FOR POINT, AREA, AND LINE SOURCES

by

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At BATTELLE - INSTITUT E.V., Frankfurt/Main
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24 - 26 September, 1975

A GAUSSIAN-PLUME ALGORITHM FOR POINT, AREA, AND LINE SOURCES

by D. Bruce Turner and William B. Petersen

INTRODUCTION

The PAL algorithm is intended for making air pollutant concentration estimates for a small portion of an urban area. The sources considered are point, area, and line sources. The principal use of the algorithm is to estimate the increase in pollutant concentrations caused by a new facility such as a shopping area, a sports stadium with included parking lot, or a facility as large as an airport and its associated emissions.

PAL is not intended to estimate concentrations for an entire urban area. Because of the details which the algorithm considers, such as edge effects from area sources, the application to an entire urban area would, in general, be prohibited by computer costs. Also, since meteorological data are entered hour by hour, a normal run for this algorithm would be to simulate a period of from 1 to 24 hours. Calculations for more than several 24-hour periods would also be costly.

The intended users of the PAL algorithm are the air pollution meteorologist and the air pollution control engineer who are attempting to estimate air quality on a scale of tens to hundreds of meters in the vicinity of the sources considered. The PAL algorithm offers a considerable amount of flexibility to the user. Any or all of the six source subroutines may be utilized. The user also has the option of employing a diurnal variation to emission rates, and allowing the wind speed to change with height.

This algorithm is useful for estimating short-term dispersion of stable pollutants using Gaussian plume, steady-state assumptions. The Gaussian point source equation is the heart of the algorithm. Numerical integration of the point source equation is used for both line and area sources. Meteorological data used by the algorithm are for hourly periods. Averages of concentrations for up to 24 hours can be obtained directly by averaging hourly estimates.

TYPES OF SOURCES CONSIDERED AND INPUTS REQUIRED

The PAL algorithm can consider six types of sources. In any single execution, any combination of these six source types can be used. However, the maximum number of input sources for any given type cannot exceed thirty. All input data are read in by the main program. The input parameters for the six source types will be discussed in this section.

POINT SOURCES

The treatment of point source in PAL is similar to that in many other air quality simulation models. In order to calculate plume rise, the stack gas temperature in combination with stack gas volume flow, or stack inside diameter and stack gas velocity are required. Point source information consists of the following for each source:

- Point source strength, g $\sec^{-1}$
- Physical stack height, m
- Stack gas temperature, °K
- Stack gas velocity, m $\sec^{-1}$
- Stack inside top diameter, m
- Stack gas volume flow, $m^3 \sec^{-1}$
- East coordinate of stack, km
- North coordinate of stack, km
- Initial σ_y, m
- Initial σ_z, m

AREA SOURCES

In PAL the shape of area sources may be squares or rectangles. Boundaries must be oriented north-south and east-west. There are no special restrictions about source size. A unique feature of PAL is that negative area source strengths can be considered in order to account for smaller areas with no emission within larger area sources. For example, an area occupied by buildings within a large parking lot can be given an area source strength equal to that of the parking lot but negative in sign. (See "Specific Example" section.) Area source information consists of the following for each source:

- Area source strength, g $\sec^{-1} m^{-2}$
- Area source height, m (Assumed to be effective height.)
- East coordinate of south-west corner, km
- North coordinate of south-west corner, km

- East-west length of area source, km
- North-south length of area source, km

HORIZONTAL LINE SOURCES

Line sources of finite horizontal extent can be considered by PAL. Single-line sources or multiple-line sources such as parallel lanes of traffic, hereinafter referred to as multi-lane sources, can be input into the model. The end points of the line source are points A and B. Provision for some initial size of the source, such as turbulent mixing of effluent in the wake of vehicles or aircraft engines, is through initial σ_y's and σ_z's. Line source information consists of the following for each source:

- Line source strength, g $sec^{-1} m^{-1}$
- Line source height, m
- Number of lanes if multilane, dimensionless
- East coordinate of point A, km
- North coordinate of point A, km
- East coordinate of point B, km
- North coordinate of point B, km
- Initial σ_y, m
- Initial σ_z, m

Line source strength as a 1-hour average for mobile sources can be calculated in the manner shown on p 3 of Zimmerman and Thompson (1975) by multiplying appropriate vehicle emission factors in either g mi^{-1} $vehicle^{-1}$

or g km^{-1} $vehicle^{-1}$ by the vehicle flow rate (vehicles hr^{-1}) and appropriate conversion factors. The vehicle emission factor can be found from publications such as EPA's AP-42 (second edition). These vehicle emission factors should be corrected for average vehicle speed along the specific segment, as most pollutant emissions vary with vehicle speed. For multi-lane sources, additional information is needed. An emission rate is given for each lane. Lanes are ordered from left to right when looking from point A to point B. The additional information below is expected by the program if the number of lanes given above is greater than one. Only an even number of lanes can be considered. For multi-lane sources, the points A and B are expected midway between the outermost lanes, that is, in the middle of the median for a roadway.

- Total width of line source, m
- Width of median of line source, m
- Line source strength for each lane, g $sec^{-1}m^{-1}$

HORIZONTAL CURVED SOURCES

In addition to line sources, curved sources can also be included in PAL. The curved sources are assumed to be of constant radius. Like the line sources, they can be single or multi-lane sources. In order to describe the curved segment, the coordinates of the end points as well as the coordinates of one point in between are needed. This point need not be in the middle of the curve. Emissions are handled the same as for horizontal line sources. As with line sources, multi-lane curved sources have to have an even number of lanes in order to be handled as one source. Points A and C are the end points of the curved source. Point B is a point on the curve between A and C. Curved source information consists of the following for each source:

- East coordinate of point A, km
- North coordinate of point A, km
- East coordinate of point B, km
- North coordinate of point B, km
- East coordinate of point C, km
- North coordinate of point C, km
- Curved source height, m
- Number of lanes, dimensionless
- Width of curved source, m
- Width of median, m
- Initial σ_y, m
- Initial σ_z, m
- Curved source strength for each lane, g $sec^{-1}m^{-1}$

SPECIALIZED LINE SOURCES

The inclusion of specialized line sources in PAL is to account for additional variations in two variables. The first is to account for a changing effective height of the line source from one end of the source to the other. The effective height is the height above the surrounding terrain. The second is to account for variations of the emission rate from one end of the source to the other.

For specialized line sources the emission in the usual line source units, g $\sec^{-1} m^{-1}$, is calculated within the computer program for each point evaluated by dividing the input emission rate by the average velocity of vehicles past that point. The input emission rate, g $\sec^{-2}$, can be determined by multiplying the average vehicle emission rate, g $\min^{-1}$ vehicle^{-1}, [for example, see pp 59-61 of Kunselman et al. (1974)] by the vehicle flow rate, vehicles hr^{-1}, for this segment and appropriate conversion factors. Neither the specialized line nor curved source will accept multi-lane input as a single source. The input parameters for the specialized line source follow:

- Emission rate, g $\sec^{-2}$
- Height of point A, m
- Height of point B, m
- East coordinate of point A, km
- North coordinate of point A, km
- East coordinate of point B, km
- North coordinate of point B, km
- Initial speed of vehicles, m $\sec^{-1}$ (at point A)
- Final speed of vehicles, m $\sec^{-1}$ (at point B)
- Initial σ_y, m
- Initial σ_z, m

SPECIALIZED CURVED SOURCES

The specialized curved source algorithm is very similar to the specialized line source routine except it incorporates the added feature of allowing the source to be a curve with a constant radius. Input for the curved sources is identical to the specialized line source except for the addition of the coordinates of a third point along the curved source to define the curved path. As with the horizontal curved sources, points A and C are the ends of the curved segment,and point B is a point on the curve between A and C. The initial speed is at point A; the final speed is at point C. This speed can be increasing or decreasing from point A to C. The input parameters for the specialized curved sources follow:

- Curved-source emission rate, g $\sec^{-2}$
- Height of point A, m
- Height of point B, m
- East coordinate point A, km
- North coordinate of point A, km
- East coordinate of point B, km
- North coordinate of point B, km
- East coordinate of point C, km
- North coordinate of point C, km
- Initial speed of vehicles, m $\sec^{-1}$ (at point A)
- Final speed of vehicles, m $\sec^{-1}$ (at point C)
- Initial σ_y, m
- Initial σ_z, m

RECEPTORS

Receptors may be located at any position relative to the air pollutant sources. However, common sense should be used so that receptors are not positioned in the center of lanes of traffic, etc. The data required for each receptor consist of the east and north coordinates of the receptor and the height of the receptor above ground level. PAL is designed to make estimates over relatively level terrain. The receptor height should not be used in an attempt to simulate topographic differences. The height of a receptor is the distance of that receptor above the local ground level, not the height of the ground above some reference plane. The three receptor parameters are:

- East coordinate of receptor, km
- North coordinate of receptor, km
- Height of receptor above ground, m

METEOROLOGICAL DATA

The input of meteorological data for each simulated hour, up to 24 hours, follows all required source and receptor data. Care should be taken to ensure that the meteorological data are representative of the source-receptor locality. Availability airport data may not be representative of an urban or suburban site. Wind speed and direction are especially sensitive to the local environment especially in the vicinity of buildings. Depending upon the nature of the problem being considered, special instrumentation may be established in the field in order to gather representative meteorological data —— of wind, in particular. At the present state of development of this algorithm, the dispersion parameter values incorporated in PAL are those given in EPA's Workbook of Atmospheric Dispersion Estimates (Turner, 1974). These are most representative for open countryside, that is, rural areas. Therefore if the source-receptor locality is in an essentially rural area, the Pasquill stability class can be determined in the usual way, as in the Workbook. However, if the area of concern is in a more built-up area, the stability may need to be modified toward more unstable conditions in order to perform the calculations with the increased dispersion caused by the thermal and roughness characteristics of the locality.

Mixing height will frequently be of little importance if source-receptor distances are small. Mixing height is the top of the unstable or neutral layer near the ground. Therefore, mixing height is not used if the lowest atmospheric layer is stable. Mixing height is usually more nearly the same over larger areas than wind speed or wind direction. However, urban influences may cause the existance of a neutral layer at the surface and a mixing height at night compared to stable conditions for this period in the rural area.

The ambient air temperature is used only for the calculation of plume rise for the point sources. If there are no point sources, the air temperature is not required.

Since a meteorological data card is read for each simulated hour, some additional optional data related to diurnal emission rates are included with the meteorological data. If the option is employed to vary the emission rates of the sources, a dimensionless factor for each source type is read in for each hour. The computations for each source are then multiplied by this factor using the individual emissions previously read. For example, if information indicates that for this hour the emissions from all point sources are about half the emission rates previously read in, the factor would be 0.5. Or, if the emissions are thought to be about 30 per cent higher for this hour, the factor would be 1.30.

The meteorological and diurnal factor input parameters follow:

- Wind direction, deg
- Wind speed, m sec^{-1}
- Pasquill stability class, dimensionless
- Mixing height, m
- Ambient air temperature, °K

- -

- Diurnal variation for point sources, dimensionless
- Diurnal variation for area sources, dimensionless
- Diurnal variation for horizontal line sources, dimensionless
- Diurnal variation for curved sources, dimensionless
- Diurnal variation for specialized line sources, dimensionless
- Diurnal variation for specialized curved sources, dimensionless

GENERAL FRAMEWORK OF ALGORITHM

The algorithm consists of a main program which reads in the information and also prints the output and subroutines which are called to perform the bulk of the calculations. Control information is initially read into the program to determine what source types are going to be used. Controls for the two optional features are also included. The wind speed can be assumed constant for all heights for each simulated hour, or the option employed to include an increase in wind speed with height above 10 meters, assuming the wind is constant below 10 meters. An exponential increase with height is assumed with the exponent of the profile dependent upon the stability class. Emission rates can be assumed constant with the values as read in, or the option may be employed to multiply calculations by a factor for each source type for each simulated hour.

After reading the control data, the emission information - that which is expected depending upon the indicated controls - is read for each parameter within each source type. Any number or combination of the six source types may be used. All input to the program is printed as output after being read so that a complete listing is available.

Receptor coordinates and heights are read following all emission information. Meteorological data for each hour are then included for up to 24 hours.

After reading all required input for sources, receptors, and meteorology, the subroutines that are needed are called to perform the calculations for each source type.

The concentration output is arranged in a table with one line for each receptor. The receptors are numbered sequentially as read. This receptor number and the receptor coordinates are given on this printed line. In addition to total concentration from all sources, the partial concentrations due to each source type (not each individual source) are also included. For details, see "Specific Example" section.

BASIS FOR CALCULATIONS

The following assumptions are made: 1) Dispersion from points, and area and line elements result in Gaussian distributions in both the horizontal and vertical directions through the dispersing plume from that point or element, and therefore steady-state Gaussian plume equations can be used for point sources and the integration of these equations for line and area sources. 2) Concentration estimates may be made for each hourly period using the mean meteorological conditions appropriate for each hour. 3) The total concentration at a receptor is the sum of the concentrations estimated from all point and area sources, that is, concentrations are additive.

POINT SOURCES

The basis for the point source calculations is the point source form of the Gaussian diffusion equation. A computation is made for each source-receptor pair. The upwind distance of a source from an individual receptor is first calculated. If this distance is negative, indicating that the source is downwind of the receptor, no calculation for this source-receptor pair is needed. For positive upwind distances, the crosswind distance of the source from the receptor is also determined. Plume rise for each source is calculated once for each hourly simulation period. The plume rise is added to the physical stack height to give effective height of emission. The dispersion equation is then evaluated. The standard deviations of plume spreading are determined as functions of the Pasquill stability class and of the source-receptor distance. As each concentration from a point source at a receptor is calculated, it is added to the accumulated concentrations from point sources for that particular hour.

AREA SOURCES

The calculation of concentrations from area sources is simulated by a number of finite crosswind line sources. If all four corners of the area source have positive upwind distances from the receptor, an integration will be performed starting from the corner of minimum distance to the corner of maximum distance. If some but not all of the corners have a negative upwind distance, then the integration will be performed from an upwind distance of zero to the greatest distance. If all four corners have negative distances from the receptor, this indicates the entire area source is downwind of the receptor position. A number of crosswind (that is, perpendicular to the upwind direction) line sources at various distances from the minimum to the maximum distance are considered. Concentrations for each of these distances are calculated using the infinite line source form of the Gaussian equation. This concentration from an infinite line source is corrected for the finite extent of each individual line by considering the distance in units of σ_y of each end of the line from the upwind azimuth line through the receptor. The fraction of the area under a Gaussian curve between these limits determines the correction. An integration is performed using the concentration contribution from a number of lines and considering the distance between lines. This integration is the first estimate of the concentration from the area source. A second estimate is made by using the first estimate with additional calculations made for lines lying half-way between all the previously calculated lines. This second estimate is compared with the first and if the second falls within a set criteria the second estimate is taken as the final concentration. If the second estimate is not within the criteria, additional calculations are made, each time choosing additional lines lying half-way between lines of the previous total set.

LINE SOURCES

The calculation of concentrations from line sources is done by an integration of the point source equation in the same manner as in Zimmerman and Thompson (1975). Distances to the end points of the lines are determined in terms of upwind and crosswind distances. The line source is limited to those parts of the line which contribute concentrations to the receptor. Calculations are made for a number of points on the line, and, assuming linear change in concentration between these points, an estimate of the concentration from the line is determined. This first estimate is then compared to a second estimate, made by taking additional points between the existing ones and then assuming linear changes of concentrations between each of the adjacent points. The second estimate is compared to the first, and if it falls within a set criteria, the second estimate is taken as the concentration. If the second estimate is not within the criteria, third and subsequent estimates may be required by taking additional points. Estimates for curved sources are determined similarly by evaluating for locations on the curve and integrating. For the specialized line and curved sources, provisions are included to determine the height and emission rate for each location evaluated.

SPECIFIC EXAMPLE

In order to help clarify some of the terms and procedures mentioned previously, an example run of the PAL model is shown. The source inputs into PAL are one point source, two area sources, two line sources, and one curved source, shown in Figure 1.

Consider this example as a simple model of a shopping center, where the hatched region is occupied by buildings and walkways and the rest of the regions within the rectangular boundary represent the parking lot. Notice that the area source strength for the shopping area is the same as that for the parking lot but negative in sign (see Table 1). The effect of the negative area source strength is to make the concentration from the shopping area equal to zero. Also within the area source is a point source whose point source strength and other input variables are shown in Table 1.

The highway around the area source consists of two four-lane line sources and one four-lane curved source. The length of the two line sources is one kilometer. The line source strengths for each lane of the two line sources and the curved source are given in Table 1. For this example run no specialized line or specialized curved sources were used.

Table 1 is a copy of the computer output from PAL. The output begins with a listing of all input parameters and options used. PINA ana PINL are the area and line source integration accuracies. Under the column titled "Source Included," the "yes's" refer to the different subroutines that are used in the model. In the second column headed "Wind Increase With Height," the "no's" mean that the option of having the wind increase with height is not used. Notice also that no average concentration is calculated, since only one hour's data are input, nor is the diurnal variation in emission option used. First, the sources are listed in the input section of the print-out. Following the source input information, the coordinates of the receptors are printed out. Meteorological information follows next and concludes the listing of the input. Included in the meteorological input is the value of the diurnal variation fraction for each source type. In this case the diurnal variation in emissions is not used, and the fractions are set to 1.0 by the program. The final output for this particular run is the "CONCENTRATIONS AT RECEPTORS." Concentrations are given in g m^{-3} for each source type and a total for all types. At the conclusion of this print-out, three options are available besides termination of the job. These depend upon the value punched on a control card. The options are:

1. To start a new problem giving all the input information.
2. To leave all sources the same but input new information on receptors and meteorology.
3. To input new information on meteorology.

SUMMARY

The PAL algorithm is intended to evaluate the contribution of sources within a limited area. This can be the impact of a new facility in a relatively rural environment or the additional impact of a number of sources added to a portion of an urban area. Gaussian plume dispersion equations are used with straight- and curved- lines, sloping-lines, area, and point sources. Briggs plume rise is used. Receptors may be at elevated heights above ground level. Level terrain is assumed. Concentration estimates are for short time periods between one hour and 24 hours. The algorithm is not intended for calculations for entire urban areas or for a long period of time. Although this algorithm may be best run in a batch mode, it is anticipated that a conversational version will also be made available for UNAMAP (Users Network for Applied Modeling of Air Pollution).

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APPENDIX - DISPERSION AND ANALYTIC GEOMETRY EQUATIONS USED IN PAL

EXPRESSIONS

These expressions are used in the discussions that follow:

$$g_1 = \exp\,(-0.5\ y^2/\sigma_y^2)$$

$$g_2 = \exp\,[-0.5(z-H)^2/\sigma_z^2] + \exp\,[-0.5(z+H)^2/\sigma_z^2]$$

$$g_3 = \sum_{N=-\infty}^{\infty} \left\{ \exp\,[-0.5(z-H+2NL)^2/\sigma_z^2] + \exp\,[-0.5(z+H+2NL)^2/\sigma_z^2] \right\}$$

(This infinite series converges rapidly, and evaluation with the integer, N, varying from -4 to +4 is usually sufficient.)

here: H = effective height of emission, meters

L = mixing height, the top of the unstable layer, meters

y = crosswind distance, meters

z = receptor height above ground, meters

σ_y = standard deviation of plume concentration distribution in the vertical, meters

σ_z = standard deviation of plume concentration distribution in the vertical, meters

POINT SOURCE COMPUTATIONS

The upwind distance, x, and the crosswind distance, y, of a point source from a receptor (see Figure 2) are given by:

$$x = (S_p - S_r)\cos\Theta + (R_p - R_r)\sin\Theta \qquad \text{(A1)}$$

$$y = (S_p - S_r)\sin\Theta - (R_p - R_r)\cos\Theta \qquad \text{(A2)}$$

where R_p, S_p are the coordinates of the point source; R_r, S_r are the coordinates of the receptor, and θ is the wind direction (the direction from which the wind blows). The units of x and y will be the same as those of the coordinate system R, S. Frequently a conversion is required in order to express x and y in meters or kilometers.

The contribution to the concentration, χ_p, from a single point source to a receptor is given by one of the three following equations where χ_p is in g m^{-3}, Q is point source emission rate in g sec^{-1}, u is wind speed in m sec^{-1}, and σ_y and σ_z are evaluated for the upwind distance x, and the stability class.

For stable conditions or unlimited mixing:

$$\chi_p = Q\, g_1\, g_2/(2\pi\sigma_y\sigma_z u) \qquad \text{(A3)}$$

In unstable or neutral conditions and if σ_z is greater than 1.6 times the mixing height, L, the distribution below the mixing height is uniform with height provided that both the effective height, H, and the receptor height, z, are below the mixing height:

$$\chi_p = Q\, g_1/[\sigma_y L u (2\pi)^{\frac{1}{2}}] \qquad \text{(A4)}$$

(If H or z is above the mixing height, $\chi_p = 0$.)

In all other unstable or neutral conditions, that is, if σ_z is less than 1.6 times the mixing height:

$$\chi_p = Q\, g_1\, g_3/(2\pi \sigma_y \sigma_z u) \tag{A5}$$

AREA SOURCE COMPUTATIONS

Equation (A1) is used to determine the upwind distance, x, of a corner of the area source with coordinates R_p, S_p from a receptor with coordinates R_r, S_r.

By evaluating x for the four corners of the area source, the maximum and minimum upwind distances of the area source from the receptor are determined (see Figure 3). (If the x's are negative for all four corners, indicating the entire area source is downwind, no calculation is performed. If the minimum x is negative, the minimum considered is zero, as no computations need to be performed for that portion of the area source downwind of the receptor.)

For a given upwind distance, x, from a receptor at point R_r, S_r, the north coordinate, S_L, of the intersection of a crosswind line with a north-south boundary given by $R = R_b$ is:

$$S_L = \frac{x - (R_b - R_r)\sin\theta}{\cos\theta} + S_r \tag{A6}$$

The coordinates of this intersection are then R_b, S_L.

Similarly, for a given upwind distance, x, from a receptor at R_r, S_r, the east coordinate, R_L, of the intersection of a crosswind line with an east-west boundary given by $S = S_b$ is:

$$R_L = \frac{x - (S_b - S_r)\cos\theta}{\sin\theta} + R_r \qquad \text{(A7)}$$

The coordinates of this intersection are then R_L, S_b.

Using the above relationships and special tests for $\sin\theta = 0$ and $\cos\theta = 0$, along with the equations for the four boundaries of the area source, the two intersections (A and B) of the crosswind line and the boundaries of the area source can be found.

The two crosswind distances, y_A and y_B, of these points from the receptor can be found using equation (A2).

Assuming that the distances y_A and y_B are in km, the number of standard deviations in the Gaussian distribution of these points from the upwind azimuth through the receptor are given by:

$$s_A = (1000\ y_A) / \sigma_y \qquad \text{(A8)}$$

$$s_B = (1000\ y_B) / \sigma_y \qquad \text{(A9)}$$

where σ_y is in meters and is determined for the distance x and the atmospheric stability. s_A and s_B can be used to determine the fractional portion of the area under a Gaussian curve between these limits. In PAL this is accomplished by interpolating between values in a table. The values in the table are from -3.8 s to 3.8 s at intervals of 0.1 s.

To account for the finite length of the line source, the fraction determined above is used to correct the calculation for a crosswind line source, infinite in extent.

The first estimate, C_1, for the concentration, χ_A, from an area source is given by:

$$C_1 = \frac{q_A}{u} \left[\frac{f_c(x_{min})}{2} + \frac{f_c(x_{max})}{2} + \sum_{i=1}^{9} f_c\,(x_{min} + i\,\Delta\,x) \right] \Delta x \qquad \text{(A10)}$$

where q_A is area emission rate

u is mean wind speed

f_c is defined below

and $\Delta x = (x_{max} + x_{min})\ /10$

The second estimate, C_2, for the concentration, χ_A, from an area source is given by:

$$C_2 = \frac{C_1}{2} + \frac{q_A \Delta x}{2u} \sum_{j=1}^{10} f_c\,(x_{min} - \Delta x/2 + j\,\Delta x) \qquad \text{(A11)}$$

The second estimate is compared with the first estimate and if the ratio of the two are within a set criteria, $\chi_A = C_2$. If not, a third estimate is made, by evaluating f_c for additional lines, then comparing with the second estimate. The notation f_c means each f as defined below is corrected for the finite length of each line. The following defines the function, f, which is related to the concentration contribution from an infinite crosswind line source.

For stable conditions or unlimited mixing:

$$f = g_2 / [\sigma_z (2\pi)^{\frac{1}{2}}] \tag{A12}$$

where g_2 was defined at the beginning of this appendix.

In unstable or neutral conditions and if σ_z is greater than 1.6 times the mixing height, L, the distribution below the mixing height is uniform with height provided that both the effective height, H, and the receptor height, z, are below the mixing height:

$$f = 1/L \tag{A13}$$

(If H or z is above the mixing height, f = 0.)

In all other unstable or neutral conditions, that is, if σ_z is less than 1.6 times the mixing height:

$$f = g_3 / [\sigma_z (2\pi)^{\frac{1}{2}}] \tag{A14}$$

LINE SOURCE COMPUTATIONS

The line source and receptor relationships are shown in Figure 4. Points A and B are the beginning and ending points of the line. x and y are the upwind and crosswind distances from a receptor to a point on the line source. x and y are given by equations (A1) and (A2).

R_p and S_p are the coordinates of any point on the line and are functions of length, ℓ, along the line and total length of the line, D:

$$R_p = \frac{\ell}{D} (R_B - R_A) + R_A \tag{A15}$$

$$S_p = \frac{\ell}{D} (S_B - S_A) + S_A \tag{A16}$$

Since R_p and S_p are functions of ℓ (see Figure 2), x and y are also functions of ℓ.

The upwind distances, x, of the receptor to points A and B are calculated. If both of these x's are negative, then the line source is downwind of the receptor and the concentration at the receptor due to the line source is zero. If either or both x's are positive, it is determined if there is a point on the line source directly upwind of the receptor. The equation for the line source is:

$$(R - R_A) / (S - S_A) = (R_B - R_A) / (S_B - S_A) \tag{A17}$$

The equation of the line through the receptor in the upwind direction is:

$$R - R_r = (S - S_r) \tan \theta \tag{A18}$$

Solving these two equations simultaneously for R and S by letting:

$$m = (R_B - R_A) / (S_B - S_A).$$

$$S = \frac{m S_A - S_r \tan \theta + R_r - R_A}{m - \tan \theta} \tag{A19}$$

and $$R = (S - S_r) \tan \theta + R_r \tag{A20}$$

This resulting intersection R, S (see point I, Figure 4) must be tested to see if it is upwind of the receptor by testing for positive x using equation (A1), and if it lies on the line source between points A and B. If both of these conditions are met, the line source is considered to be made up of two segments: The first segment from point A to the intersection point, and the second segment from the intersection point to point B. The point directly upwind has a significant contribution to the concentration at the receptor. The line is broken into two segments so that this point will be considered in the integration estimate that follows. If there are two segments to the line source, the total concentration is given by the sum of the two concentrations from the segments.

The concentration from a line source is then given by the following equation.

$$\chi = \frac{q_\ell}{u} \int_0^D f_p \, d\ell \tag{A21}$$

where:

q_ℓ = line source emission rate, g $\sec^{-1} m^{-1}$

u = wind speed, m $\sec^{-1}$

D = line source length, meters

and f_p = point source dispersion function

The point source dispersion function is given by one of the three following equations where σ_y and σ_z are evaluated for the upwind distance, x, and the stability class.

For stable conditions, or unlimited mixing:

$$f_p = \frac{g_1 g_2}{2\pi \sigma_y \sigma_z} \tag{A22}$$

where g_1 and g_2 have been previously defined.

In unstable or neutral conditions, if σ_z is greater than 1.6 times the mixing height, L (meters), the distribution below the mixing height is uniform with height regardless of source or receptor height, provided both are less than the mixing height.

$$f_p = \frac{g_1}{\sigma_y L (2\pi)^{\frac{1}{2}}} \tag{A23}$$

In all other unstable or neutral conditions:

$$f_p = \frac{g_1 g_3}{2\pi \sigma_y \sigma_z} \tag{A24}$$

It should be noted that in PAL, initial σ_y's and σ_z's, such as to account for initial dispersion in the turbulent wake behind vehicles, are input values. The virtual distance for the given stability class is calculated within the algorithm. These virtual distances are added to the physical distances prior to determining σ_y and σ_z for each concentration computation.

The integral, A21, is evaluated using the trapezoidal rule by making a first estimate, C_1, given by:

$$C_1 = \frac{q_\ell \Delta\ell}{u} \left\{ \frac{1}{2} \left[f_p(o) + f_p(10\Delta\ell) \right] + \sum_{i=1}^{9} f_p(i\Delta\ell) \right\} \qquad \text{(A25)}$$

where $\Delta\ell = D/10$, and f_p is defined above. For each of the 11 evaluations of f_p, the upwind distance, x, of the point on the line from the receptor is determined as a function of $\Delta\ell$, and x is used to determine σ_x and σ_y in the function f_p. Portions of the line where f_p equals zero are eliminated and the line is redefined. Then equation (A25) is again evaluated.

A second estimate, C_2, is determined from:

$$C_2 = \frac{C_1}{2} + \frac{q_\ell \Delta\ell}{2u} \left[\sum_{j=1}^{10} f_p(-\Delta\ell/2 + j\Delta\ell) \right] \qquad \text{(A26)}$$

A calculation is made of $(C_2 - C_1)/C_2$. If this value is within a set criteria, $\chi = C_2$. If not within the criteria, a third estimate is made by evaluating f_p for additional points midway between those points previously calculated and assuming linear concentration change between adjacent points (trapezoidal rule). This is continued until the approximation to the integral converges, that is, until two successive estimates are within the criteria. The last estimate is the concentration, χ, from this line source.

For line sources with an intersection point upwind from the receptor, the contribution from the second segment must also be determined. If the point directly upwind was not used to break the line into two segments, and the entire line source is considered as one segment, it is possible for the entire portion of the line that contributes significantly to the concentration to be between two of the eleven points, and thus an erroneous concentration of zero would result.

For line sources with multiple lanes, the integral would be evaluated for each lane and the concentration summed to represent the total concentration at that receptor from the line source.

CURVED SOURCE COMPUTATIONS

Figure 5 shows the curved source and receptor relationships. Points A and C are the end points of the curved path. Point B is an arbitrary point on the curve between A and C. The curve is assumed to be of constant radius.

The radius of the circle, of which the curve is a part, is determined in the following way: The coordinates of point D midway between A and B on a chord are found by averaging the R and S coordinates of A and B. Similarly the coordinates of point E midway between B and C on a chord are found. The perpendicular bisector of a chord of a circle will pass through the center of a circle. Also the slope of the perpendicular bisector is the negative reciprocal of the slope of the chord. The slope of chord AB is:

$$(R_B - R_A) / (S_B - S_A)$$

and the slope of chord BC is:

$$(R_c - R_B) / (S_c - S_B)$$

The slope of the bisector through D, call this m_1, is:

$$- (S_B - S_A) / (R_B - R_A) = m_1$$

The slope of the bisector through E, call this m_2, is:

$$- (S_C - S_B) /(R_C - R_B) = m_2$$

The resulting equation of the bisector through D is:

$$R_o - R_D = m_1 (S_o - S_D) \tag{A27}$$

and the equation of the bisector through E is:

$$R_o - R_E = m_2 (S_o - S_E) \tag{A28}$$

R_o and S_o can be determined from these two equations, for example:

$$S_o = (m_1 S_D - m_2 S_E - R_D + R_E) / (m_1 - m_2) \tag{A29}$$

$$\text{and} \quad R_o = m_1 (S_o - S_D) + R_D \tag{A30}$$

The radius of the circle can then be determined from the coordinates of the center (R_0, S_0) and any one of the three points on the curve, for example:

$$\rho = \sqrt{(S_A - S_0)^2 + (R_A - R_0)^2} \quad \text{(A31)}$$

In order to provide a proper estimate of the concentrations from the curved source at a receptor, it is desirable to determine if a line in the upwind direction from the receptor intersects the curve. The equation of the line through the receptor in the direction of the upwind azimuth is:

$$R - R_r = (S - S_r) \tan \Theta \quad \text{(A32)}$$

The equation of the circle of which the curve is a part is:

$$\rho^2 = (S - S_0)^2 + (R - R_0)^2 \quad \text{(A33)}$$

The two possible intersections of the line and the circle are found by solving a quadratic equation for one of the two variables, for example, of the form:

$$a\,R^2 + b\,R + c = 0 \quad \text{(A34)}$$

where $a = 1 + \cot^2\Theta$ (A35)

$$b = -2\,R_r \cot^2\Theta + 2\,S_r \cot\Theta - 2\,S_0 \cot\Theta - 2\,R_0 \quad \text{(A36)}$$

$$\text{and } c = R_r^{\,2} \cot^2\Theta - 2\,R_r\,S_r \cot\Theta - 2\,R_r\,S_0 \cot\Theta - 2\,S_0\,S_r$$

$$+ S_r^{\,2} + S_0^{\,2} + R_0^{\,2} - \rho^2 \quad \text{(A37)}$$

Two possible values of R are found from:

$$R = \frac{-b \pm \sqrt{b^2-4ac}}{2a} \qquad \text{(A38)}$$

If b^2-4ac is negative, R has imaginary roots and there is no intersection of the circle and the line. If b^2-4ac is zero, the line is tangent to the circle and there is one intersection. If b^2-4ac is positive there are two intersections and both roots of the equation are found. If one or two values of R are found, then one or two values of S are found from:

$$S = (R-R_r) \cot\theta + S_r \qquad \text{(A39)}$$

If one or more intersections were found for the line and circle, the upwind distance of this (these) point(s) from the receptor can be determined using equation (A1). If this value is negative, indicating the point is downwind from the receptor, it need not be considered further. However, for a point with a positive x, it must be determined if this intersection on the circle is also on the curve, that is, between points A and C.

The direction from the center of the circle (R_o, S_o) to a point (R_p, S_p) on the circle is:

$$\phi = \tan^{-1} [(R_p-R_o) / (S_p - S_o)] \qquad \text{(A40)}$$

The directed azimuth from the circle's center to any intersection and to points A, B, and C can then be found. With some logic to consider the crossover point (from 360° to 0°), it can be determined if the ϕ for the intersection is within the range of ϕ swept out by the curve.

After determining if any intersections are on the curve, the curve is considered in three pieces if there are two intersections, two if there is one intersection, and as a single curve if there are no intersections. The computation is done very similarly to that for line sources. Whereas the length along the line is used to make calculations at intervals for the line source, the variation of the azimuth from the center of the circle, ϕ, is used for the curved source. The coordinates of a point on the curve for which the concentration contribution is being evaluated are found from:

$$R_p = R_o + \rho \sin \phi \qquad \text{(A41)}$$

$$S_p = S_o + \rho \sin \phi \qquad \text{(A42)}$$

The upwind and crosswind distances, x and y, of a given point on the curve with coordinates (R_p, S_p) from the receptor (R_r, S_r) are calculated as previously using equations (A1) and (A2). The same point source dispersion function, f_p, as given in the "Line Source Computations" section is used.

Portions of the curve that contribute no concentration to the receptor are eliminated, and the curve is redefined. An initial estimate of the concentration from the remaining curve is made using eleven equally spaced points along the curve. These and the ten points in between are then used for a second estimate. Comparison is made of the two estimates and, as with the area and line source estimates, if these two are within the given criteria, the concentration is that of the second estimate. If additional estimates are made, concentration contributions for additional points, midway between these points already considered, are determined assuming the concentration varies linearly between adjacent points, that is, trapezodial integration.

If the curve was broken into pieces because of intersections, the contribution from the additional pieces must be determined as above.

TABLE 1

```
EXAMPLE PROBLEM OF PAL 'A GAUSSIAN-PLUME ALGORITHM FOR POINT,AREA,LINE SOURCES'

PINA =    .02000 PINL =    .02000

              SOURCE     WIND INCREASE
             INCLUDED    WITH  HEIGHT

   POINT       YES            NO

   AREA        YES            NO

HORIZONTAL
LINE SOURCE    YES            NO

   CURVE
PATH SOURCE    YES            NO

  SPECIAL
LINE SOURCE    NO             NO

  SPECIAL
PATH SOURCE    NO             NO                       AVERAGE     NO   DIURNAL    NO


•••P O I N T   S O U R C E S•••
  NO.    POINT    PHYSICAL    STACK     STACK      STACK     VOLUME       COORDINATES       INITIAL SIGMAS
         SOURCE    HEIGHT     TEMP       GAS     DIAMETER     FLOW       EAST     NORTH       Y        Z
        STRENGTH  (METERS)   (DEG-K)  VELOCITY  (METERS)  (CU M/SEC)   (KM)      (KM)       (M)      (M)
         (G/SEC)                       (M/SEC)

   1         5.00     10.0    320.0       .00        .00     12.00      .240      .185      1.0      1.0


••A R E A   S O U R C E S•••
  NO.      AREA       AREA          COORDINATES          AREA SIZE
          SOURCE     SOURCE          SW-CORNER
         STRENGTH    HEIGHT      EAST      NORTH    EAST-WEST NORTH-SOUTH
      (G/SEC-M**2) (METERS)      (KM)      (KM)       (KM)       (KM)

   1      .00020000      .0       .240      .150      .070       .030
   2      .00020000      .0       .120      .070      .200       .120


••H O R I Z O N T A L   L I N E   S O U R C E S•••
  NO.     LINE       LINE                   COORDINATES
         SOURCE     SOURCE        POINT A                 POINT B            INITIAL SIGMAS                NO.    TOTAL    MEDIAN
        STRENGTH    HEIGHT     EAST      NORTH        EAST       NORTH         Y          Z                 OF     WIDTH     WIDTH
       (G/SEC-M)   (METERS)    (KM)      (KM)         (KM)       (KM)         (M)        (M)              LANES  (METERS)  (METERS)
                                                                                                              4.      20.0        .0
   1    .00700000        .0     .160      .037       1.160       .037        3.00       1.50
   2    .00150000        .0     .160      .032       1.160       .032        3.00       1.50
   3    .00190000        .0     .160      .028       1.160       .028        3.00       1.50
   4    .00200000        .0     .160      .023       1.160       .023        3.00       1.50
                                                                                                              4.      20.0        .0
```

TABLE 1 (CONTINUED)

```
       5    .00050000          .0      .063      .110      .063     1.110      3.00      1.50
       6    .00080000          .0      .068      .110      .068     1.110      3.00      1.50
       7    .00060000          .0     -.072      .110      .072     1.110      3.00      1.50
       8    .00100000          .0      .077      .110      .077     1.110      3.00      1.50


 * *C U R V E D   H O R I Z O N A L   P A T H   S O U R C E S * * *
 NO.    LINE        LINE                       COORDINATES
       SOURCE      SOURCE       POINT A                     POINT M              POINT B            INITIAL SIGMAS         NO.    TOTAL      MEDIAN
      STRENGTH     HEIGHT    EAST      NORTH           EAST       NORTH     EAST       NORTH        Y            Z         OF     WIDTH      WIDTH
     (G/SEC-M)    (METERS)   (KM)      (KM)            (KM)       (KM)      (KM)       (KM)        (M)          (M)       LANES  (METERS)   (METERS)
  1  .00200000      .000     .160      .030            .110       .042      .070       .110       3.00         1.50        4      20.00        .00
  2  .00030000      .000     .160      .030            .110       .042      .070       .110       3.00         1.50        4      20.00        .00
  3  .00150000      .000     .160      .030            .110       .042      .070       .110       3.00         1.50        4      20.00        .00
  4  .00190000      .000     .160      .030            .110       .042      .070       .110       3.00         1.50        4      20.00        .00


 * * R E C E P T O R S * * *
     NO.     RREC(KM)  SREC(KM)     Z (M)

       1       .170      .120        .0
       2       .120      .070        .0
       3       .098      .040        .0
       4       .060      .013        .0
       5       .240      .090        .0
       6       .240      .070        .0
       7       .240      .050        .0
       8       .240      .010        .0


 * * M E T E O R O L O G Y * * *
     NO.  THETA(DEG)     U (M/SEC)  KST      HL (M)   T (DEG-K)    P (MB)  DIURNAL VARIATIONS (FRACTIONS OF GIVEN Q)
                                                                                                HORIZONAL  CURVED    SPECIAL   SPECIAL
                                                                           POINT      AREA       LINE       PATH      LINE      PATH
      1.        45.         3.0          4      1000.       293.        960.  1.0000     1.0000     1.0000     1.0000    1.0000    1.0000


 * *C O N C E N T R A T I O N S   A T   R E C E P T O R S * * *
   CONCENTRATIONS IN GRAMS PER CUBIC METER                            FROM        FROM      FROM       FROM
 HOUR RECEPTOR     RECEPTOR COORDINATES    FROM        FROM        HORIZONAL   CURVED    SPECIAL    SPECIAL
        NO.      EAST    NORTH   HEIGHT    POINTS      AREAS        LINES       PATHS     LINES      PATHS       TOTAL


   1     1       .170     .120     .00    2.315-08    3.877-03    0.000       0.000     0.000      0.000      3.877-03
   1     2       .120     .070     .00    1.360-05    4.572-03    0.000       0.000     0.000      0.000      4.586-03
   1     3       .098     .040     .00    5.622-05    1.683-03    1.032-17    7.688-04  0.000      0.000      2.508-03
   1     4       .060     .013     .00    1.112-04    1.210-03    9.338-12    4.317-04  0.000      0.000      1.753-03
   1     5       .240     .090     .00    0.000       3.854-03    0.000       0.000     0.000      0.000      3.854-03
   1     6       .240     .070     .00    0.000       4.037-03    0.000       0.000     0.000      0.000      4.087-03
   1     7       .240     .050     .00    0.000       1.473-03    4.311-12    0.000     0.000      0.000      1.473-03
   1     8       .240     .010     .00    0.000       3.312-04    1.021-03    0.000     0.000      0.000      1.352-03
```

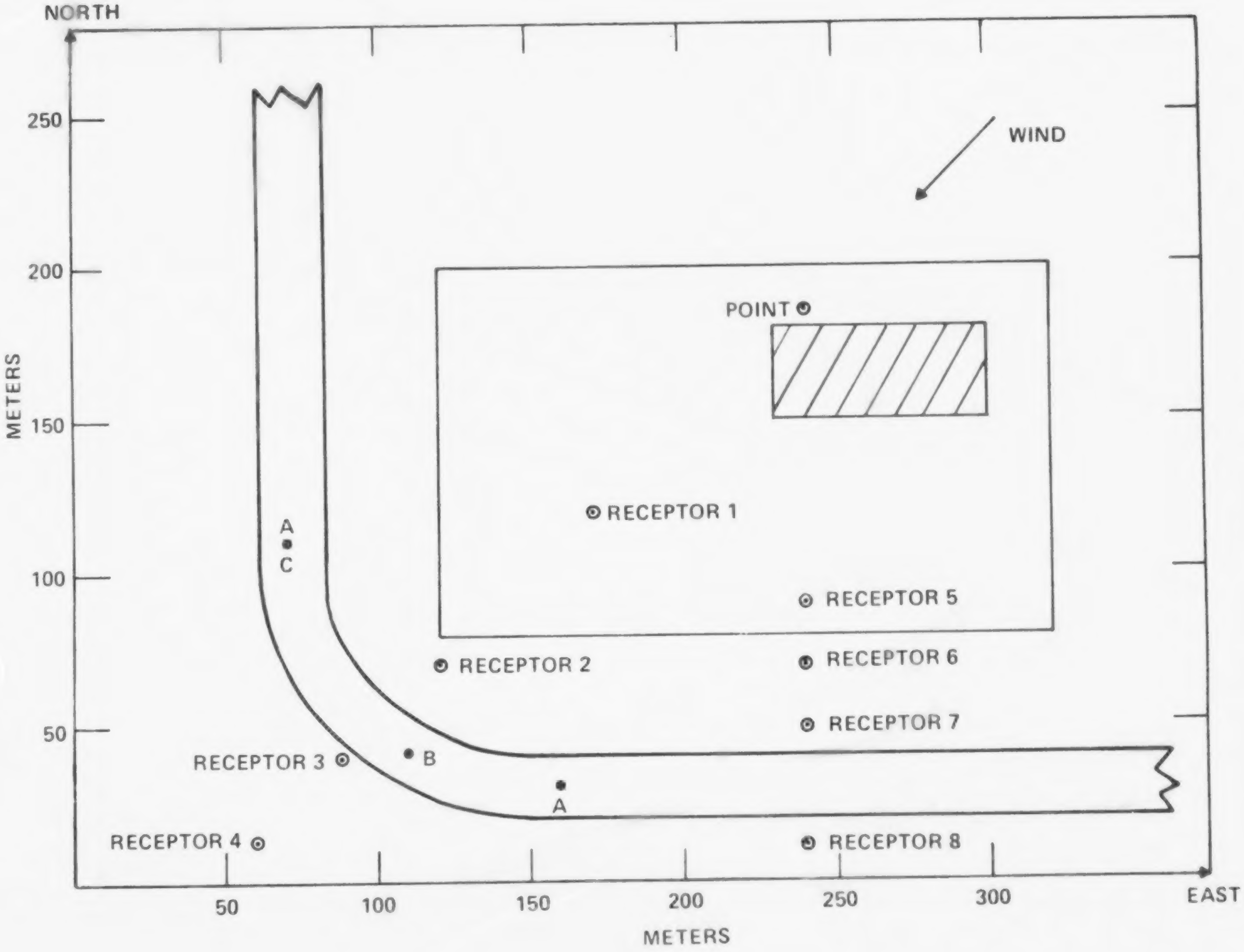
NORTH
250
200
150
100
50
METERS
WIND
POINT
RECEPTOR 1
RECEPTOR 2
RECEPTOR 3
RECEPTOR 4
RECEPTOR 5
RECEPTOR 6
RECEPTOR 7
RECEPTOR 8
A
C
B
A
50
100
150
200
250
300
EAST
METERS

Figure 1

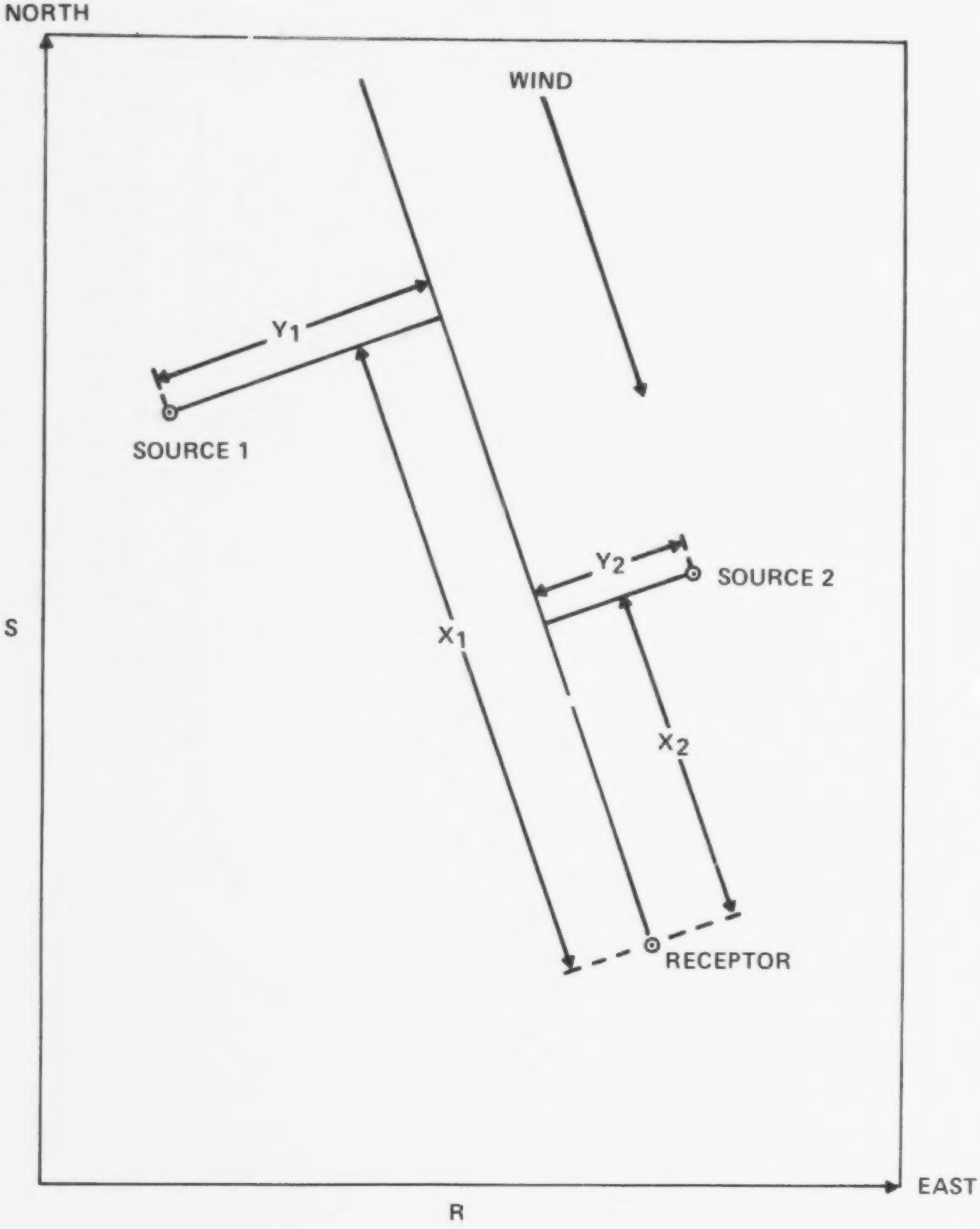
NORTH
WIND
Y1
SOURCE 1
Y2
SOURCE 2
S
X1
X2
RECEPTOR
EAST
R

Figure 2. Upwind and crosswind distances of point sources from a receptor.

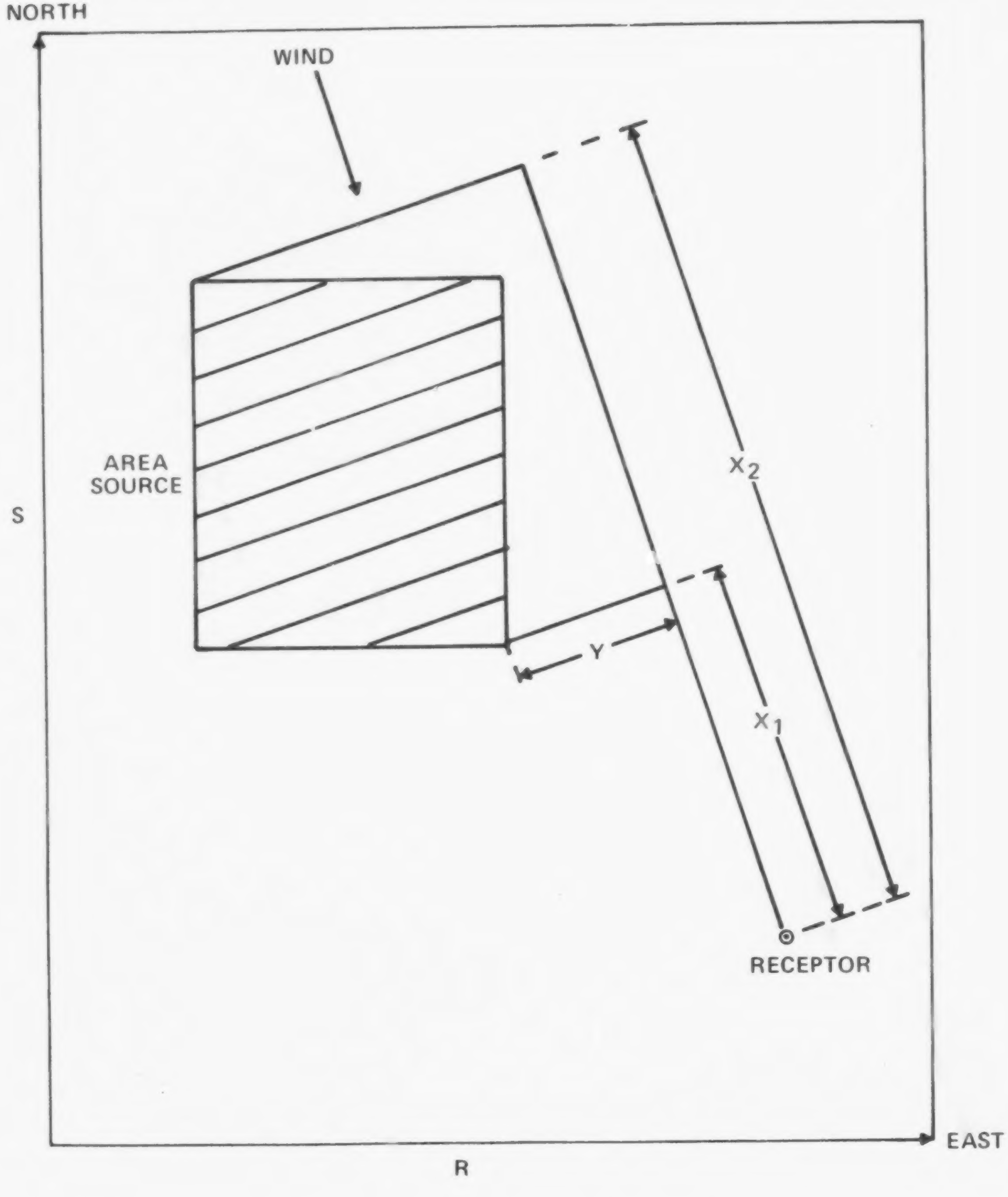
NORTH
WIND
AREA SOURCE
S
X2
Y
X1
RECEPTOR
EAST
R

Figure 3. Minimum, X_1, and maximum, X_2, upwind distances of an area source from a receptor and crosswind line sources.

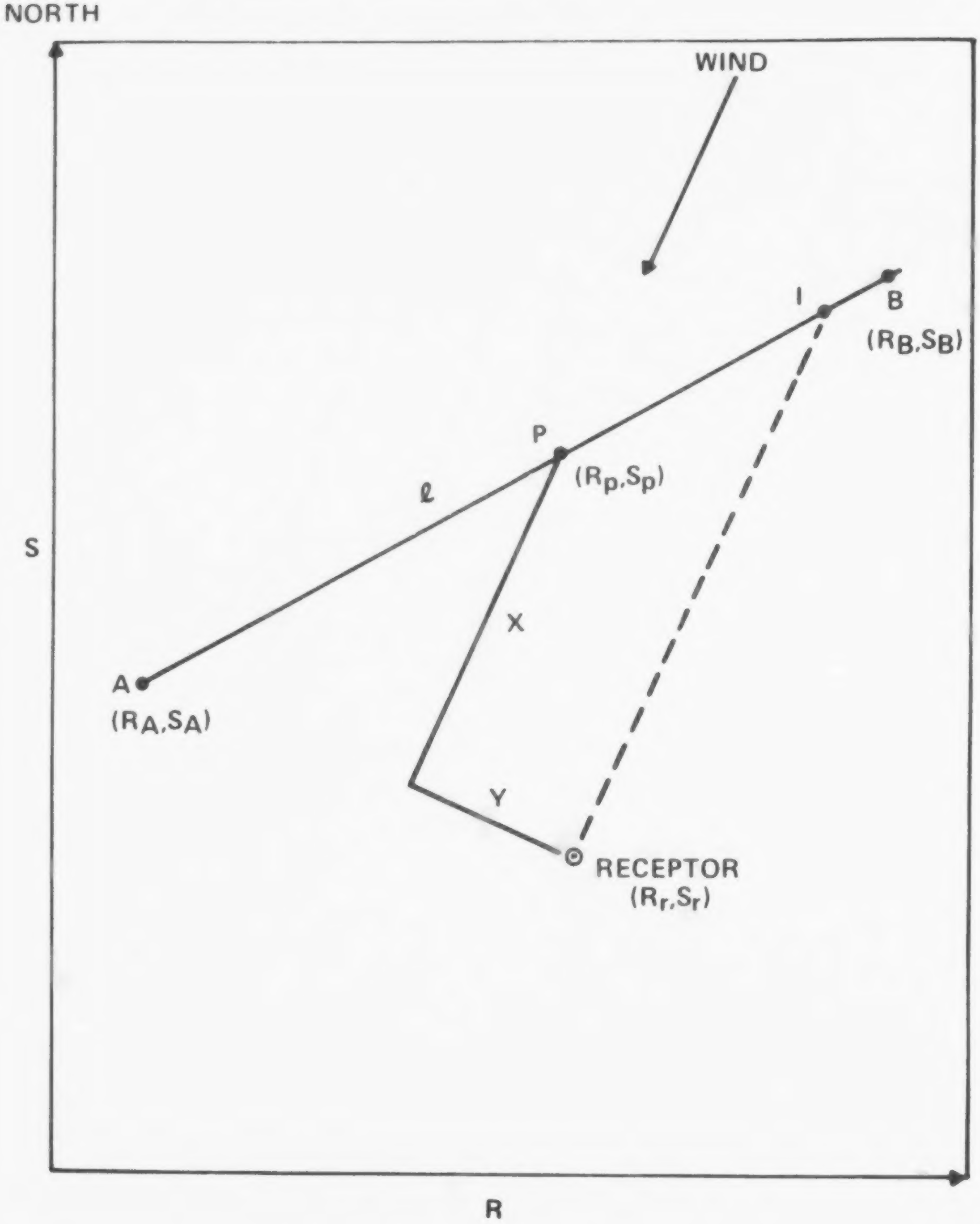
NORTH
WIND
I
B
(R_B, S_B)
P
(R_p, S_p)
ℓ
S
X
A
(R_A, S_A)
Y
RECEPTOR
(R_r, S_r)
R

Figure 4. Line source and receptor relationships.

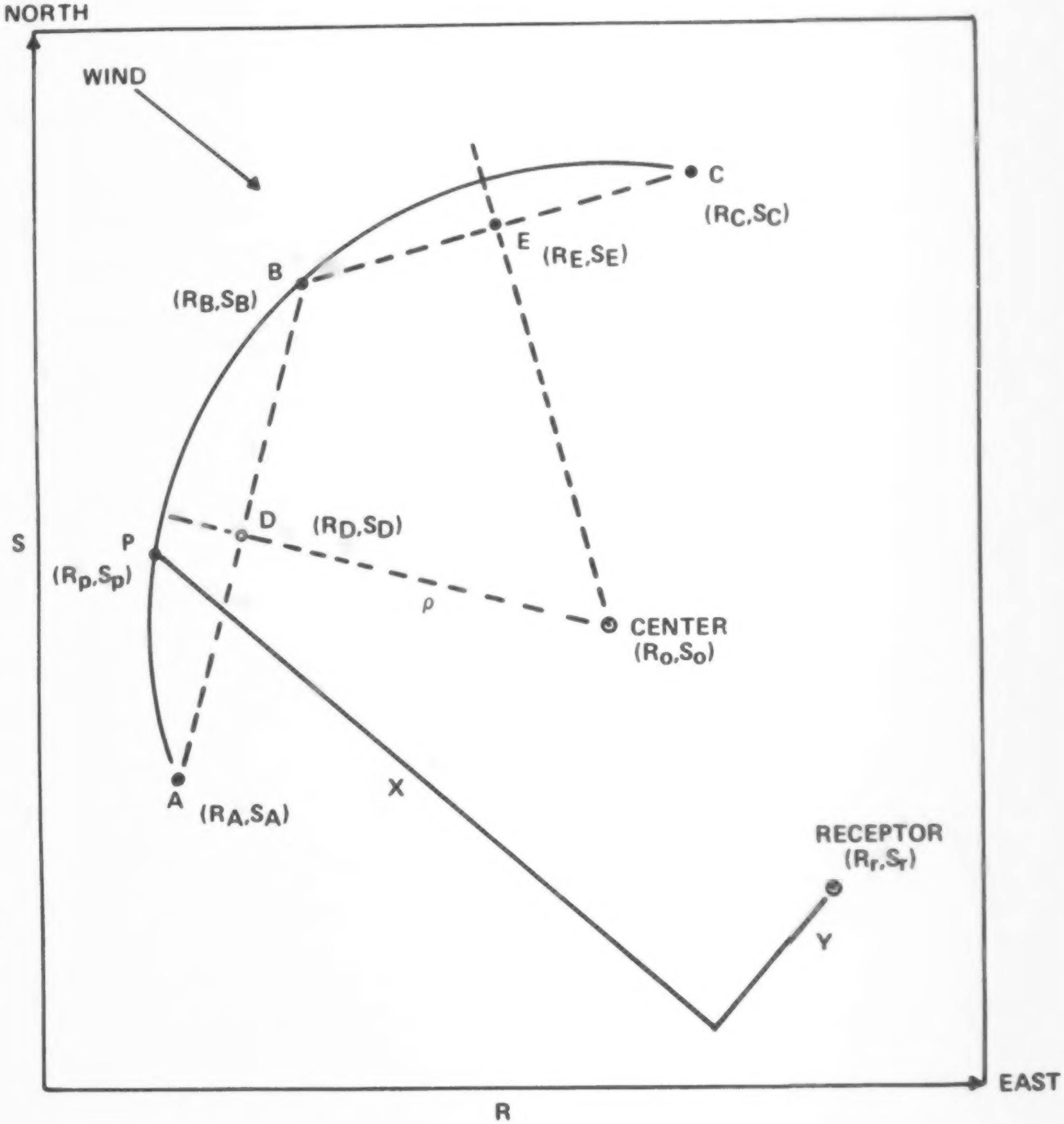
NORTH
WIND
C
(R_C, S_C)
E
(R_E, S_E)
B
(R_B, S_B)
D
(R_D, S_D)
S
P
(R_p, S_p)
ρ
CENTER
(R_o, S_o)
A
(R_A, S_A)
X
RECEPTOR
(R_r, S_r)
Y
EAST
R

Figure 5. Curved source and receptor relationships.

PART 2

The slant (or special line) and special curved path source calculations are made in a similar way as the line source and curved source calculations, respectively. Unlike Equation A21, the concentration from special sources is given by

$$\chi = \frac{1}{u} \int_{o}^{D} q_{\ell} \, f_{p} \, d_{\ell}, \tag{1}$$

where q_{ℓ} is now no longer a constant but varies along the source. This section will describe how q_{ℓ} is calculated for special sources.

The acceleration of the vehicles is assumed constant and equal to

$$a = \frac{V_f - V_o}{t} \tag{2}$$

where a = acceleration of the vehicles,

v_o = initial vehicle speed at point A (see Figures 4 and 5),

V_f = final vehicle speed at B or C (see Figures 4 and 5),

t = total time of travel.

The vehicle speed at any point "P" on the source is given by

$$V_p = at_p + V_o \tag{3}$$

where v_p = vehicle speed at P, and

t_p = time of travel to P.

The vehicle acceleration can also be expressed as

$$a = \frac{V_f^2 - V_o^2}{2X_f} \tag{4}$$

where X_f = total distance of travel.

The distance of travel to any point "P" can be expressed as

$$X_p = \frac{1}{2} a\ t_p^2 + V_o\ t_p \tag{5}$$

where X_p = distance of travel to P.

Solving for t_p in Equation 5 and substituting in Equation 3,

$$V_p = \left[V_o^2 + \frac{X_p}{X_f} (V_f^2 - V_o^2) \right]^{\frac{1}{2}} \tag{6}$$

The emission rate q_ℓ $(\frac{g}{\text{sec-m}})$ is now given by

$$q_\ell = \frac{TV\ (\frac{veh}{HR})\ \times\ EF(\frac{g}{\text{sec-veh}})}{3600\ (\frac{sec}{HR})\ \times\ v_p\ (\frac{m}{sec})} \tag{7}$$

where TV = traffic volume.

The emission rate is inversely proportional to V_p. In order to ensure that q_ℓ will not approach infinity as V_p goes to zero, a simple technique is used to set a minimum vehicle speed. The minimum speed (V_s) is calculated using the traffic volume and a gross estimate of average vehicle length (VL).

$$V_s = \frac{TV\ (\frac{veh}{HR})\ \times\ VL\ (\frac{m}{veh})}{3600\ (\frac{sec}{HR})} \tag{8}$$

V_s is then in $(\frac{m}{sec})$, and physically it is the slowest speed the vehicles could be going and still maintain the traffic volume. If V_p is less than V_s, then V_p is set equal to V_s.

For most applications this change in vehicle speed will have negligible effect on the concentration estimates.

APPENDIX B

FORTRAN STATEMENTS

PAL

```
C        PAL  VERSION 78001
C         PAL CALCULATES HOURLY CONCENTRATIONS FROM POINT,AREA, AND
C         LINE SOURCES.
C         PAL READS ALL INPUT DATA CARDS.SOURCE INPUT DATA CARDS
C         INCLUDE POINT,AREA,HORIZONAL LINE,SPECIAL LINE,HORIZONAL
C         CURVED PATH,AND SPECIAL CURVED PATH DATA CARDS.
C         ALL SOURCE INPUT DATA CARDS ARE OPTIONAL.
C         METEOROLOGY AND RECEPTOR INPUT DATA CARDS ARE
C         NOT OPTIONAL.
C         THE FOLLOWING SUBROUTINES ARE CALLED BY PAL.
C               POINT--POINT SOURCE SUB-MODEL.
C               AREA--AREA SOURCE SUB-MODEL.
C               HRZLN--HORIZONAL LINE SOURCE SUB-MODEL.
C               CRVLN--CURVED PATH SOURCE SUB-MODEL.
C               SPCLN--SPECIAL LINE SOURCE SUB-MODEL.
C               SPCCR--SPECIAL CURVED PATH SOURCE SUB-MODEL.
      COMMON /SOP/ QP(31),HPP(31),TSP(31),VSP(31),DP(31),VFP(31),RQP(31)
     1,SQP(31),SYOP(31),SZOP(31),CONP(31,24),DVP(25),IUZP
      COMMON /SOA/ QA(31),HQ(31),RQ(31),SQ(31),DEST(31),DNOR(31),CONA(31
     1,24),DVA(25),IUZA
      COMMON /SOL/ QLN(31),HLN(31),RAQ(31),SAQ(31),RBQ(31),SBQ(31),SYO(3
     11),SZO(31),CONLH(31,24),DVH(25),IUZH
      COMMON /SOCP/ QLNS(31),HLNS(31),RBQS(31),SBQS(31),RMQS(31),SMQS(31
     1),REQS(31),SEQS(31),SIYO(31),SIZO(31),CONCLN(31,24),DDVH(31),IUZC,
     2RADIUS(31),NLANE(31)
      COMMON /SOLS/ QLS(31),HAS(31),HBS(31),RAS(31),SAS(31),RBS(31),SBS(
     131),SYOS(31),SZOS(31),CONLS(31,24),DVS(25),IUZS,SPDI(31),SPDF(31),
     2TVSL(31),VSSL(31)
      COMMON /SOCS/ QLNA(31),HCL(31),RBQA(31),SBQA(31),RMQA(31),SMQA(31)
     1,REQA(31),SEQA(31),SIYA(31),SIZA(31),CONCLA(31,24),DVHA(31),IUZE,S
     2PEI(31),SPEF(31),TVCL(31),VSCL(31)
      COMMON /REC/ RR(31),SR(31),ZR(31)
      COMMON /WEA/ WTHET(25),WU(25),MKST(25),WHL(25),WTA(25),UHGT
      DIMENSION ALP(20), CONT(30,24), ACP(31), ACA(31), ACLH(31), ACLS(3
     11), ACT(31), QLT(20), YAN(3), ACLC(31), QLTS(31), ACAC(31)
      DATA YAN /'   ',' NO','YES'/,IVER/78001/
      IRD=5
      IWRI=6
      MAXQ=31
      MAXR=31
10    READ (IRD,790) ALP
      WRITE (IWRI,800) ALP,IVER
C        ALP IS 80 COLS OF ALPHANUMERIC INFORMATION TO HELP IDENTITY OUT
      READ (IRD,810) PINA,PINL,IQP,IUZP,IQA,IUZA,IQLH,IUZH,IQLC,IUZC,IQL
     1S,IUZS,IQAC,IUZE,IAVG,IDRNL,UHGT
C      PINA  X.XXXX TEST FOR AREA INTEGRATION ACCURACY.  (DIMENSIONLESS)
C      PINL  X.XXXX TEST FOR LINE INTEGRATION ACCURACY.  (DIMENSIONLESS)
C      IQP   X      CONTROL FOR POINT SOURCES.           (DIMENSIONLESS)
C      IUZP  X      WIND INCREASE WITH HEIGHT,POINT      (DIMENSIONLESS)
C      IQA   X      CONTROL FOR AREA SOURCES.            (DIMENSIONLESS)
C      IUZA  X      WIND INCREASE WITH HEIGHT,AREA.      (DIMENSIONLESS)
C      IQLH  X      CONTROL FOR HORIZ. LINE SOURCES.     (DIMENSIONLESS)
C      IUZH  X      WIND INCREASE WITH HGT.,HORIZ.LINE.  (DIMENSIONLESS)
```

```
C     IQLC  X       CONTROL FOR CURVED PATH SOURCES.     (DIMENSIONLESS)
C     IUZC  X       WIND INCREASE WITH HGT.,CURVED PATH. (DIMENSIONLESS)
C     IQLS  X       CONTROL FOR SLANT LINE SOURCES.      (DIMENSIONLESS)
C     IUZS  X       WIND INCREASE WITH HGT.,SLANT LINE.  (DIMENSIONLESS)
C     IQAC  X       CONTROL FOR SPECIAL PATH SOURCES.    (DIMENSIONLESS)
C     IUZE  X       WIND INCREASE WITH HGT.,SPECIAL PATH.(DIMENSIONLESS)
C     IAVG  X       CONTROL FOR AVG.CONCENTRATIONS.      (DIMENSIONLESS)
C     IDRNL X       CONTROL FOR DIURNAL FACTORS.         (DIMENSIONLESS)
C     UHGT  XXX.X   HEIGHT APPLICABLE TO WIND SPEED.     (M)
C        CONTROL VALUES: IQ ARE 1 FOR NON-INCLUSION, 2 FOR INCLUSION.
      WRITE (IWRI,820) PINA,PINL,YAN(IQP+1),YAN(IUZP+1),YAN(IQA+1),YAN(I
     1UZA+1),YAN(IQLH+1),YAN(IUZH+1),YAN(IQLC+1),YAN(IUZC+1),YAN(IQLS+1)
     2,YAN(IUZS+1),YAN(IQAC+1),YAN(IUZE+1),YAN(IAVG+1),YAN(IDRNL+1),UHGT
      GO TO (60,20), IQP
C        WRITE HEADING FOR POINT SOURCE INFORMATION.
20    WRITE (IWRI,830)
      I=1
30    READ (IRD,810) ICARD,QP(I),HPP(I),TSP(I),VSP(I),DP(I),VFP(I),RQP(I
     1),SQP(I),SYOP(I),SZOP(I)
C     DECIMALS MUST BE INCLUDED IN REAL VARIABLES.
C     A COMMA MUST BE PLACED BETWEEN EACH VARIABLE.
C     IF A VARIABLE IS NOT USED SET IT = TO 0.
C     ICARD=1 ON ALL SOURCE INPUT CARDS EXCEPT THE LAST THEN ICARD=2.
C        * * * P O I N T   S O U R C E   C A R D * * *
C     ICARD X          EQUALS 1 OR 2 SEE ABOVE.             (DIMENSIONLESS)
C     QP    XXXXX.XX   POINT SOURCE STRENGTH.               (G/SEC)
C     HPP   XXX.X      PHYSICAL STACK HEIGHT.               (M)
C     TSP   XXX.X      STACK GAS TEMPERATURE.               (DEG K)
C     VSP   XX.X       STACK GAS VELOCITY.                  (M/SEC)
C     DP    XX.XX      STACK INSIDE DIAMETER.               (M)
C     VFP   XXXX.X     STACK GAS VOLUME FLOW.               (M**3/SEC)
C     RQP   XXX.XXXX   EAST COORDINATE OF STACK.            (KM)
C     SQP   XXX.XXXX   NORTH COORDINATE OF STACK.           (KM)
C     SYOP  X.X        INITIAL SIGMA Y.                     (M)
C     SZOP  X.X        INITIAL SIGMA Z.                     (M)
C
      IF (I-MAXQ) 40,40,50
40    WRITE (IWRI,840) I,QP(I),HPP(I),TSP(I),VSP(I),DP(I),VFP(I),RQP(I),
     1SQP(I),SYOP(I),SZOP(I)
      IF (ICARD.GT.1) GO TO 60
      I=I+1
      GO TO 30
50    WRITE (IWRI,850) MAXQ
      CALL EXIT
60    GO TO (110,70), IQA
C        WRITE HEADING FOR AREA SOURCE INFORMATION.
70    WRITE (IWRI,860)
      J=1
80    READ (IRD,810) ICARD,QA(J),HQ(J),RQ(J),SQ(J),DEST(J),DNOR(J)
C        * * * A R E A   S O U R C E   C A R D * * *
C     ICARD X          EQUALS 1 OR 2 SEE ABOVE.             (DIMENSIONLESS)
C     QA    X.XXXXX    AREA SOURCE STRENGTH.                (G/SEC-M**2)
C     HQ    XX.XX      AREA SOURCE HEIGHT.                  (M)
```

```
C     RQ    XXX.XXX   EAST COORDINATE OF S.W. CORNER.   (KM)
C     SQ    XXX.XXX   NORTH COORDINATE OF S.W. CORNER.  (KM)
C     DEST  XX.XX     EAST-WEST SIZE.                   (KM)
C     DNOR  XX.XX     NORTH-SOUTH SIZE.                 (KM)
      IF (J-MAXQ) 90,90,100
90    WRITE (IWRI,870) J,QA(J),HQ(J),RQ(J),SQ(J),DEST(J),DNOR(J)
      IF (ICARD.GT.1) GO TO 110
      J=J+1
      GO TO 80
100   WRITE (IWRI,880) MAXQ
      CALL EXIT
110   GO TO (210,120), IQLH
C        WRITE HEADING FOR HORIZONTAL LINE SOURCE INFORMATION.
120   WRITE (IWRI,890)
C        READ A SOURCE CARD.
      K=1
130   READ (IRD,810) ICARD,HLN(K),NL,RAQ(K),SAQ(K),RBQ(K),SBQ(K),SYO(K),
     1SZO(K),WT,WM,(QLT(J),J=1,NL)
C     THE PROGRAM WILL HANDEL 1 LANE OR AN EVEN NUMBER OF LANES.
C     AN ODD NUMBER OF LANES MUST BE SEPERATED INTO 2 SOURCES
C     AN EVEN NUMBER PLUS 1 SOURCE.
C        * * * H O R I Z O N T A L   L I N E   S O U R C E   * * *
C                  C A R D   1
C     ICARD      X          EQUALS 1 OR 2 SEE ABOVE.       (DIMENSIONLESS)
C     HLN        XX.X       LINE SOURCE HEIGHT             (M)
C     NL         XX.        NO. OF LINES IF MULTI-LINE     (DIMENSIONLESS)
C     RAQ        XXX.XXXX   EAST  COORDINATE, POINT A      (KM)
C     SAQ        XXX.XXXX   NORTH COORDINATE, POINT A      (KM)
C     RBQ        XXX.XXXX   EAST  COORDINATE, POINT B      (KM)
C     SBQ        XXX.XXXX   NORTH COORDINATE, POINT B      (KM)
C     SYO        X.X        INITIAL SIGMA Y                (M)
C     SZO        X.X        INITIAL SIGMA Z                (M)
C     WT         XX.X       TOTAL WIDTH                    (M)
C     WM         XX.X       WIDTH OF MEDIAN                (M)
C     QLT(1)     X.XXXXX    LINE SOURCE STRENGTH           (G/SEC-M)
C     QLT(2)     X.XXXXX     ONE FOR EACH OF ANL SOURCES.      ,,
C       .        X.XXXXX      ORDERING IS FIRST SOURCE         ,,
C       .        X.XXXXX       STRENGTH IS FOR LEFT-MOST       ,,
C       .        X.XXXXX        LINE WHEN LOOKING FROM         ,,
C     QLT(NL)    X.XXXXX         POINT A TO POINT B            ,,
C
      IF (K-MAXQ) 140,140,200
140   IF (NL-1.) 190,190,150
150   ANL=NL
      IF (K+NL-1-MAXQ) 160,160,200
C        WT IS THE TOTAL WIDTH OF THE LINE SOURCE INCLUDING THE MEDIAN.
C        WM IS THE WIDTH OF THE MEDIAN (METERS)
C        LANES ARE ORDERED FROM LEFT TO RIGHT WHEN LOOKING FROM POINT A
C         TO POINT B.
160   WRITE (IWRI,900) ANL,WT,WM
      WL=(WT-WM)/ANL
      RA=RAQ(K)
      SA=SAQ(K)
      RB=RBQ(K)
      SB=SBQ(K)
      SYON=SYO(K)
      SZON=SZO(K)
      HLNN=HLN(K)
      DELR=RB-RA
      DELS=SB-SA
      DIST=SQRT(DELS*DELS+DELR*DELR)
      NLIM=NL/2
      ALIM=NLIM
      DO 170 KN=1,NLIM
      A=KN
      DL=(-0.5)*WM+((-1)*ALIM-0.5+A)*WL
      DUM=DL*0.001/DIST
      ID=K+KN-1
      RAQ(ID)=RA+DELS*DUM
      RBQ(ID)=RB+DELS*DUM
      SAQ(ID)=SA-DELR*DUM
      SBQ(ID)=SB-DELR*DUM
      SYO(ID)=SYON
      SZO(ID)=SZON
      QLN(ID)=QLT(KN)
      HLN(ID)=HLNN
  170 WRITE (IWRI,910) ID,QLN(ID),HLN(ID),RAQ(ID),SAQ(ID),RBQ(ID),SBQ(ID
     1),SYO(ID),SZO(ID)
      NS=NLIM+1
      AS=NS
      DO 180 KN=NS,NL
      A=KN
      DL=0.5*WM+(0.5+A-AS)*WL
      DUM=DL*0.001/DIST
      ID=K+KN-1
      RAQ(ID)=RA+DELS*DUM
      RBQ(ID)=RB+DELS*DUM
      SAQ(ID)=SA-DELR*DUM
      SBQ(ID)=SB-DELR*DUM
      SYO(ID)=SYON
      SZO(ID)=SZON
      QLN(ID)=QLT(KN)
      HLN(ID)=HLNN
  180 WRITE (IWRI,910) ID,QLN(ID),HLN(ID),RAQ(ID),SAQ(ID),RBQ(ID),SBQ(ID
     1),SYO(ID),SZO(ID)
      K=K+NL
      IF (ICARD.GT.1) GO TO 210
      GO TO 130
C        WRITE LINE  SOURCE INFORMATION.
  190 QLN(K)=QLT(1)
      WRITE (IWRI,910) K,QLN(K),HLN(K),RAQ(K),SAQ(K),RBQ(K),SBQ(K),SYO(K
     1),SZO(K)
      IF (ICARD.GT.1) GO TO 210
      K=K+1
      GO TO 130
  200 WRITE (IWRI,920) MAXQ
```

```
      CALL EXIT
210   CONTINUE
      GO TO (290,220), IQLC
C     WRITE HEADING FOR CURVED HORIZONAL LINE SOURCE INFORMATION
220   WRITE (IWRI,930)
C     READ A SOURCE CARD
      KK=0
      LL=1
230   READ (IRD,810) ICARD,HLNS(LL),NL,RBQS(LL),SBQS(LL),RMQS(LL),SMQS(L
     1L),REQS(LL),SEQS(LL),SIYO(LL),SIZO(LL),WT,WM,(QLTS(JJ),JJ=1,NL)
C     THE PROGRAM WILL HANDEL 1 LANE OR AN EVEN NUMBER OF LANES.
C     AN ODD NUMBER OF LANES MUST BE SEPERATED INTO 2 SOURCES
C     AN EVEN NUMBER PLUS 1 SOURCE.
C     A COMMA MUST BE PLACED BETWEEN EACH VARIABLE
C   * * *  C U R V E D   P A T H   S O U R C E S   * * *
C     ICARD X         EQUALS 1 OR 2 SEE ABOVE.          (DIMENSIONLESS)
C     HLNS  XX.X      PATH SOURCE HEIGHT.               (M)
C     NL    XX        NUMBER OF LANES.                  (DIMENSIONLESS)
C     RBQS  XXX.XXXX  EAST COORDINATE,PT.A              (KM)
C     SBQS  XXX.XXXX  NORTH COORDINATE,PT.A.            (KM)
C     RMQS  XXX.XXXX  EAST COORDINATE,PT.B.             (KM)
C     SMQS  XXX.XXXX  NORTH COORDINATE,PT.B.            (KM)
C     REQS  XXX.XXXX  EAST COORDINATE,PT.C.             (KM)
C     SEQS  XXX.XXXX  NORTH COORDINATE,PT.C.            (KM)
C     SIYO  X.X       INITIAL SIGMA Y.                  (M)
C     SIZO  X.X       INITIAL SIGMA Z.                  (M)
C     WT    XX.X      TOTAL WIDTH OF PATH.              (M)
C     WM    XX.X      WIDTH OF MIDIAN.                  (M)
C     QLTS  X.XXXXX   PATH SOURCE STRENGTH.             (G/SEC-M)
C                     ONE FOR EACH LANE.
C                     ORDERING OF EMISSION RATES
C                     ARE FROM OUTSIDE LANES TO
C                     INSIDE.
C
      ANL=NL
      NLANE(LL)=NL
      A=1.
      ALIM=ANL/2.
      WL=(WT-WM)/ANL
      DO 270 KL=1,NL
      KK=KK+1
      IF (KK.GT.31) GO TO 280
      QLNS(KK)=QLTS(KL)
C       RADIUS IS A CORRECTION FACTOR TO ADJUST THE RADIUS
C       FOR DIFFERENT LANES.
      RADIUS(KK)=(A*.5*WM+ALIM*WL-.5*WL*A)*.001
      ALIM=ALIM-1.
      IF (ALIM.LT.0.1.AND.ALIM.GT.-.1) ALIM=-1.
      IF (ALIM.LT.0.) A=-1.
      IF (KL.EQ.1) GO TO 240
      GO TO 250
240   WRITE (IWRI,940) KK,QLNS(KK),HLNS(LL),RBQS(LL),SBQS(LL),RMQS(LL),S
     1MQS(LL),REQS(LL),SEQS(LL),SIYO(LL),SIZO(LL),NL,WT,WM
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      GO TO 270
250   IF (KL.GT.2) GO TO 260
      WRITE (IWRI,770)
260   WRITE (IWRI,780) KK,QLNS(KK)
270   CONTINUE
      IF (ICARD.GT.1) GO TO 290
      LL=LL+1
      GO TO 230
280   WRITE (IWRI,950) MAXQ
290   GO TO (340,300), IQLS
C        WRITE HEADING FOR SLANT OR VERTICAL LINE SOURCE INFORMATION.
300   WRITE (IWRI,960)
C        READ A SOURCE CARD.
      L=1
310   READ (IRD,810) ICARD,QLS(L),HAS(L),HBS(L),RAS(L),SAS(L),RBS(L),SBS
     1(L),SPDI(L),SPDF(L),SYOS(L),SZOS(L),TVSL(L),VSSL(L)
C     A COMMA MUST BE PLACED BETWEEN EACH VARIABLE
C        * * * S L A N T   O R   V E R T I C A L   L I N E
C     ICARD X          EQUALS 1 OR 2 SEE ABOVE.          (DIMENSIONLESS)
C     QLS   X.XXXXX    LINE SOURCE STRENGTH.             (G/SEC)
C     HAS   XX.X       HEIGHT OF POINT A.                (M)
C     HBS   XX.X       HEIGHT OF POINT B.                (M)
C     RAS   XXX.XXXX   EAST COORDINATE,POINT A.          (KM)
C     SAS   XXX.XXXX   NORTH COORDINATE,POINT A.         (KM)
C     RBS   XXX.XXXX   EAST COORDINATE,POINT B.          (KM)
C     SBS   XXX.XXXX   NORTH COORDINATE,POINT B.         (KM)
C     SPDI  XXX.X      SPEED AT POINT A.                 (M/SEC)
C     SPDF  XXX.X      SPEED AT POINT B.                 (M/SEC)
C     SYOS  X.X        INITIAL SIGMA Y.                  (M)
C     SZOS  X.X        INITIAL SIGMA Z.                  (M)
C     TVSL  XXXXX.     VEHICLE VOLUME.                   (VEH/HR)
C     VSSL  XX.X       GROSS ESTIMATE OF VEH. SIZE.      (M)
C
      IF (L-MAXQ) 320,320,330
320   WRITE (IWRI,970) L,QLS(L),HAS(L),HBS(L),RAS(L),SAS(L),RBS(L),SBS(L
     1),SPDI(L),SPDF(L),SYOS(L),SZOS(L),TVSL(L),VSSL(L)
      IF (ICARD.GT.1) GO TO 340
      L=L+1
      GO TO 310
330   WRITE (IWRI,980) MAXQ
      CALL EXIT
340   GO TO (390,350), IQAC
C     WRITE HEADING FOR SPECIAL PATH SOURCE INFORMATION
350   WRITE (IWRI,990)
C     READ A SOURCE CARD
      LC=1
360   READ (IRD,810) ICARD,QLNA(LC),HCL(LC),RBQA(LC),SBQA(LC),RMQA(LC),S
     1MQA(LC),REQA(LC),SEQA(LC),SPEI(LC),SPEF(LC),SIYA(LC),SIZA(LC),TVCL
     2(LC),VSCL(LC)
      IF (LC.GT.30) GO TO 370
C     A COMMA MUST BE PLACED BETWEEN EACH VARIABLE
C  * * * S P E C I A L   P A T H   S O U R C E S * * *
C
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C     ICARD X          EQUALS 1 OR 2 SEE ABOVE.          (DIMENSIONLESS)
C     QLNA  X.XXXXX    PATH SOURCE STRENGTH.             (G/SEC)
C     HCL   XX.X       PATH SOURCE HEIGHT.               (M)
C     RBQA  XXX.XXXX   EAST COORDINATE,POINT A.          (KM)
C     SBQA  XXX.XXXX   NORTH COORDINATE,POINT A.         (KM)
C     RMQA  XXX.XXXX   EAST COORDINATE,POINT B.          (KM)
C     SMQA  XXX.XXXX   NORTH COORDINATR,POINT B.         (KM)
C     REQA  XXX.XXXX   EAST COORDINATE,POINT C.          (KM)
C     SEQA  XXX.XXXX   NORTH COORDINATE,POINT C.         (KM)
C     SPEI  XXX.X      SPEED AT POINT A.                 (M/SEC)
C     SPEF  XXX.X      SPEED AT POINT C.                 (M/SEC)
C     SIYA  X.X        INITIAL SIGMA Y.                  (M)
C     SIZA  X.X        INITIAL SIGMA Z.                  (M)
C     TVCL  XXXXX.     VEHICLE VOLUME.                   (VEH/HR)
C     VSCL  XX.X       GROSS ESTIMATE OF VEH. SIZE.      (M)
C
      WRITE (IWRI,1000) LC,QLNA(LC),HCL(LC),RBQA(LC),SBQA(LC),RMQA(LC),S
     1MQA(LC),REQA(LC),SEQA(LC),SPEI(LC),SPEF(LC),SIYA(LC),SIZA(LC),TVCL
     2(LC),VSCL(LC)
      IF (ICARD.GT.1) GO TO 380
      LC=LC+1
      GO TO 360
370   WRITE (IWRI,1010) MAXQ
380   CONTINUE
C         WRITE HEADING FOR PRINT-OUT OF RECEPTOR INFORMATION.
390   WRITE (IWRI,1020)
C         READ A RECEPTOR CARD.
      N=1
400   READ (IRD,810) ICARD,RR(N),SR(N),ZR(N)
C     A COMMA MUST BE PLACED BETWEEN EACH VARIABLE
C         * * * R E C E P T O R   C A R D * * *
C     ICARD X          EQUALS 1 OR 2 SEE ABOVE.          (DIMENSIONLESS)
C     RR    XXXX.XXX R COORDINATE                        (KM)
C     SR    XXXX.XXX S COORDINATE                        (KM)
C     ZR    XXX.X    HEIGHT ABOVE GROUND                 (M)
C     A COMMA MUST BE PLACED BETWEEN EACH VARIABLE
      IF (N-MAXR) 410,410,420
C         WRITE RECEPTOR INFORMATION.
410   WRITE (IWRI,1030) N,RR(N),SR(N),ZR(N)
      IF (ICARD.GT.1) GO TO 430
      N=N+1
      GO TO 400
420   WRITE (IWRI,1040) MAXR
      CALL EXIT
430   M=1
C         WRITE MET HEADING.
      WRITE (IWRI,1050)
C         READ A METEOROLOGY CARD.
440   GO TO (450,460), IDRNL
450   READ (IRD,810) ICARD,WTHET(M),WU(M),MKST(M),WHL(M),WTA(M)
      GO TO 470
460   READ (IRD,810) ICARD,WTHET(M),WU(M),MKST(M),WHL(M),WTA(M),DVP(M),D
     1VA(M),DVH(M),DDVH(M),DVS(M),DVHA(M)
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C     A COMMA MUST BE PLACED BETWEEN EACH VARIABLE
C        * * * M E T E O R O L O G Y   C A R D * * *
C     ICARD     X         EQUALS 1 OR 2 SEE ABOVE.        (DIMENSIONLESS)
C     WTHET     XXX.      WIND DIRECTION                  (DEG AZIMUTH)
C     WU        XX.X      WIND SPEED                      (M/SEC)
C     MKST      X         STABILITY CLASS                 (DIMENSIONLESS)
C     WHL       XXXX.     MIXING HEIGHT                   (M)
C     WTA       XXX.X     AMBIENT AIR SURFACE TEMP.       (DEG K)
C     DVP       X.XXX     DIURNAL VARIATION, POINT SOURCES(DIMENSIONLESS)
C     DVA       X.XXX     DIURNAL VARIATION, AREA SOURCES (DIMENSIONLESS)
C     DVH       X.XXX     DIUR. VAR., HORIZ. LINE SOURCES (DIMENSIONLESS)
C     DVS       X.XXX     DIUR. VAR., SLANT LINE SOURCES  (DIMENSIONLESS)
C     DDVH      X.XXX     DIUR. VAR., CURVE PATH SOURCES  (DIMENSIONLESS)
C     DVHA      X.XXX     DIUR.VAR.,SPECIAL PATH SOURCES  (DIMENSIONLESS)
C        THE DIURNAL VARIATION VALUES ARE THE RATIO OF THAT EMITTED
C         DURING THIS HOUR TO THE INPUT Q. IF THE SAME AS THE INPUT,
C         THE VALUE IS 1.000
470   CONTINUE
      IF (M-25) 490,480,480
480   WRITE (IWRI,1060)
      CALL EXIT
490   GO TO (500,510), IDRNL
500   DVP(M)=1.
      DVA(M)=1.
      DVH(M)=1.
      DVS(M)=1.
      DDVH(M)=1.
      DVHA(M)=1.
C        WRITE METEOROLOGY INFORMATION.
510   WRITE (IWRI,1070) M,WTHET(M),WU(M),MKST(M),WHL(M),WTA(M),DVP(M),DV
     1A(M),DVH(M),DDVH(M),DVS(M),DVHA(M)
      IF (ICARD.GT.1) GO TO 520
      M=M+1
      GO TO 440
520   CONTINUE
      DO 530 IM=1,M
      DO 530 IN=1,N
      CONP(IN,IM)=0.
      CONA(IN,IM)=0.
      CONLH(IN,IM)=0.
      CONCLN(IN,IM)=0.
      CONLS(IN,IM)=0.
      CONCLA(IN,IM)=0.
530   CONT(IN,IM)=0.
      GO TO (550,540), IQP
540   CALL POINT (M,I,N)
550   GO TO (570,560), IQA
560   CALL AREA (M,J,N,PINA)
570   GO TO (590,580), IQLH
580   CALL HRZLN (M,K,N,PINL)
590   GO TO (610,600), IQLC
600   CALL CRVLN (M.LL,N,PINL)
610   GO TO (630,620), IQLS
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620   CALL SPCLN (M,L,N,PINL)
630   GO TO (650,640), IQAC
640   CALL SPCCR (M,LC,N,PINL)
650   CONTINUE
      DO 660 IM=1,M
      DO 660 IN=1,N
660   CONT(IN,IM)=CONP(IN,IM)+CONA(IN,IM)+CONLH(IN,IM)+CONLS(IN,IM)+CONC
     1LN(IN,IM)+CONCLA(IN,IM)
      DO 670 IM=1,M
      WRITE (IWRI,1080)
      DO 670 IN=1,N
670   WRITE (IWRI,1090) IM,IN,RR(IN),SR(IN),ZR(IN),CONP(IN,IM),CONA(IN,I
     1M),CONLH(IN,IM),CONCLN(IN,IM),CONLS(IN,IM),CONCLA(IN,IM),CONT(IN,I
     2M)
      IF (M-1) 740,740,680
680   GO TO (740,690), IAVG
690   DO 700 IN=1,N
      ACP(IN)=0.
      ACA(IN)=0.
      ACLH(IN)=0.
      ACLC(IN)=0.
      ACLS(IN)=0.
      ACAC(IN)=0.
700   ACT(IN)=0.
      DO 710 IM=1,M
      DO 710 IN=1,N
      ACP(IN)=ACP(IN)+CONP(IN,IM)
      ACA(IN)=ACA(IN)+CONA(IN,IM)
      ACLH(IN)=ACLH(IN)+CONLH(IN,IM)
      ACLC(IN)=ACLC(IN)+CONCLN(IN,IM)
      ACLS(IN)=ACLS(IN)+CONLS(IN,IM)
      ACAC(IN)=ACAC(IN)+CONCLA(IN,IM)
710   ACT(IN)=ACT(IN)+CONT(IN,IM)
      DO 720 IN=1,N
      ACP(IN)=ACP(IN)/M
      ACA(IN)=ACA(IN)/M
      ACLH(IN)=ACLH(IN)/M
      ACLC(IN)=ACLC(IN)/M
      ACLS(IN)=ACLS(IN)/M
      ACAC(IN)=ACAC(IN)/M
720   ACT(IN)=ACT(IN)/M
      WRITE (IWRI,1100) M
      NDUM=0
      WRITE (IWRI,1080)
      DO 730 IN=1,N
730   WRITE (IWRI,1090) NDUM,IN,RR(IN),SR(IN),ZR(IN),,ACP(IN),ACA(IN),AC
     1LH(IN),ACLC(IN),ACLS(IN),ACAC(IN),ACT(IN)
740   READ (IRD,810,END=760) KTL
      IF (KTL) 760,760,750
750   GO TO (10,390,430,760), KTL
760   CALL EXIT
C
770   FORMAT (/,10X,'SOURCE STRENGTH FOR THE REMAINING LANES',/,15X,'LAN
     1E',5X,'SOURCE STRENGTH',/)
 780  FORMAT (17X,I2,T28,F10.8)
 790  FORMAT (20A4)
 800  FORMAT (1H1,20A4,5X,'VERSION ',I5)
 810  FORMAT ()
 820  FORMAT (1H0,'PINA =',F10.5,' PINL =',F10.5,//,14X,'SOURCE',5X,'WIN
     1D INCREASE',/,13X,'INCLUDED    WITH  HEIGHT',//,4X,'POINT',6X,A3,1
     22X,A3,//,4X,'AREA',7X,A3,12X,A3,//,1X,'HORIZONTAL',/,1X,'LINE SOUR
     3CE',3X,A3,12X,A3,//,4X,' CURVE',/,1X,'PATH SOURCE',3X,A3,12X,A3,//
     4,3X,'SPECIAL',/,1X,'LINE SOURCE',3X,A3,12X,A3,//,3X,'SPECIAL',/,1X
     5,'PATH SOURCE',3X,A3,12X,A3,10X,'AVERAGE',5X,A3,'   DIURNAL',3X,A3
     6,5X,'HEIGHT AT WIND SPEED',1X,F6.1,1X,'METERS',//)
 830  FORMAT (1H0,'* * * P O I N T   S O U R C E S * * *',/,7X,'NO.    P
     1OINT    PHYSICAL    STACK      STACK      STACK     VOLUME       COOR
     2DINATES        INITIAL SIGMAS',/13X,'SOURCE     HEIGHT     TEMP
     3  GAS    DIAMETER    FLOW        EAST      NORTH          Y          Z
     4',/12X,'STRENGTH   (METERS)   (DEG-K)  VELOCITY  (METERS)  (CU M/S
     5EC)  (KM)      (KM)       (M)        (M)'/13X,'(G/SEC)',24X,'(M/SE
     6C)',/)
 840  FORMAT (1H ,I7,3X,F10.2,2F10.1,3F10.2,2F10.3,2F10.1)
 850  FORMAT (1H0,'THE NUMBER OF POINT SOURCE CARDS EXCEED THE STORAGE A
     1LLOTTED FOR THEM IN THE DIMENSION STATEMENT:',I3)
 860  FORMAT (///,'* * * A R E A   S O U R C E S * * *',/,7X,'NO.     AR
     1EA      AREA         COORDINATES          AREA SIZE',/,13X,'SOURCE
     2  SOURCE          SW-CORNER',/,12X,'STRENGTH    HEIGHT      EAST
     3 NORTH  EAST-WEST NORTH-SOUTH',/,10X,'(G/SEC-M**2) (METERS)     (KM
     4)      (KM)      (KM)       (KM)',/)
 870  FORMAT (1H ,I7,3X,F10.8,F10.1,4F10.3)
 880  FORMAT (1H0,'THE NUMBER OF AREA SOURCE CARDS EXCEED THE STORAGE AL
     1LOTTED FOR THEM IN THE DIMENSION STATEMENT:',I3)
 890  FORMAT (///,'* * * H O R I Z O N T A L   L I N E   S O U R C E S *
     1 * *',/,7X,'NO.    LINE          LINE',17X,'COORDINATES',/,13X,'SOURC
     2E     SOURCE          POINT A',13X,'POINT B',10X,'INITIAL SIGMAS',18
     3X,'NO.     TOTAL    MEDIAN',/,12X,'STRENGTH    HEIGHT      EAST
     4 NORTH       EAST      NORTH',8X,'Y',9X,'Z',19X,'OF       WIDTH     W
     5IDTH',/,11X,'(G/SEC-M)   (METERS)     (KM)       (KM)       (KM)
     6 (KM)        (M)          (M)',17X,'LANES   (METERS) (METERS) ')
 900  FORMAT (1H ,100X,F10.0,2F10.1)
 910  FORMAT (1H ,I7,3X,F10.8,F10.1,4F10.3,2F10.2)
 920  FORMAT (1H0,'THE NUMBER OF LINE SOURCE CARDS EXCEED THE STORAGE AL
     1LOTTED FOR THEM IN THE DIMENSION STATEMENT:',I3)
 930  FORMAT (///,'* * *C U R V E D  H O R I Z O N A L  P A T H  ','S O
     1U R C E S  * * * ',/,2X,'NO.',T10,'PATH',T21,'PATH',T42,'COORDINAT
     2ES',/,T9,'SOURCE',T20,'SOURCE',T32,'POINT A',T53,'POINT B',T71,'PO
     3INT C',T87,'INITIAL SIGMAS',T108,'NO.',4X,'TOTAL     MEDIAN',/,T8,
     4'STRENGTH',T20,'HEIGHT',T29,'EAST',T38,'NORTH',T50,'EAST',T59,'NOR
     5TH',T68,'EAST',T77,'NORTH',T89,'Y',T99,'Z',T108,'OF     WIDTH
     6WIDTH',/,T7,'(G/SEC-M)',T19,'(METERS)',T29,'(KM)',T39,'(KM)',T50,'
     7(KM)',T60,'(KM)',T68,'(KM)',T78,'(KM)',T88,'(M)',T98,'(M)',T108,'L
     8ANES  (METERS)  (METERS)')
 940  FORMAT (/,2X,I2,T7,F10.8,T17,F9.3,T26,F9.3,T36,F9.3,T47,F9.3,T57,F
     19.3,T66,F9.3,T76,F9.3,T86,F7.2,T96,F7.2,T108,I2,T115,F7.2,2X,F7.2)
 950  FORMAT (///,3X,'THE NUMBER OF CURVED PATH SOURCES EXCEEDS',' THE N
     1UMBER ALLOTTED FOR THEM IN THE DIMENSION STATEMENT:',I3)
960   FORMAT (///,'* * * S L A N T   O R   V E R T I C A L   L I N E  S
     1 O U R C E S * * *',/,7X,'NO.   SOURCE',7X,'SOURCE HEIGHT',10X,'PO
     2INT A',13X,'POINT B',9X,'INITIAL  FINAL',3X,'INITIAL SIGMAS',2X,'T
     3RAFFIC',1X,'VEH.',/,12X,'STRENGTH',8X,'(METERS)',4X,2(5X,'EAST
     4  NORTH'),5X,'SPEED',4X,'SPEED',7X,'Y',6X,'Z',4X,'VOLUME',2X,'SIZE
     5',/,12X,' (G/SEC)    POINT A',3X,'POINT B',4X,4('(KM)',6X),2('(M/S
     6EC)',2X),2X,'(M)',4X,'(M)',2X,'(VEH/HR)',1X,'(M)',/)
970   FORMAT (1H ,I7,3X,F10.2,2F10.1,6F10.3,F8.2,F7.2,2X,F5.0,1X,F5.1)
980   FORMAT (1H0,'THE NUMBER OF SLANT LINE SOURCE CARDS EXCEED THE STOR
     1AGE ALLOTTED FOR THEM IN THE DIMENSION STATEMENT:',I3)
990   FORMAT (///,'* * * S P E C I A L  P A T H  S O U R C E S  * * * ',
     1/,1X,'NO.',1X,'SOURCE',4X,'SOURCE ',9X,'POINT A',11X,'POINT B',11X
     2,'POINT C',7X,'INITIAL',3X,'FINAL',4X,'INITIAL SIGMAS',2X,'TRAFFIC
     3 VEH.',/,4X,'STRENGTH',3X,'HEIGHT',7X,'EAST',4X,'NORTH',5X,'EAST',
     44X,'NORTH',5X,'EAST',4X,'NORTH',4X,'SPEED',5X,'SPEED',7X,'Y',6X,'Z
     5',5X,'VOLUME  SIZE',/,5X,'(G/SEC)',2X,'(METERS)',6X,'(KM)',5X,'(KM
     6)',5X,'(KM)',5X,'(KM)',5X,'(KM)',5X,'(KM)',4X,'(M/SEC)',2X,'(M/SEC
     7)',5X,'(M)',4X,'(M)',3X,'(VEH/HR)',1X,'(M)',/)
1000  FORMAT (1X,I2,1X,F8.2,2X,F8.1,2X,6(F8.3,1X),3X,2(F7.3,2X),1X,2F7.3
     1,2X,F5.0,1X,F5.1)
1010  FORMAT (///,' THE NUMBER OF SPECIAL PATH SOURCES EXCEEDS THE',' ST
     1ORAGE ALLOTTED FOR THEM IN THE DIMENSION STATEMENT:',I3)
1020  FORMAT (///,'* * * R E C E P T O R S * * *',/,7X,'NO.    RREC(KM)
     1 SREC(KM)    Z (M)'/)
1030  FORMAT (1H ,I10,2F10.3,F10.1)
1040  FORMAT (1H0,'THE NUMBER OF RECEPTOR CARDS EXCEED THE STORAGE',' AL
     1LOTTED FOR THEM IN THE DIMENSION STATEMENT:',I3)
1050  FORMAT (///,'* * * M E T E O R O L O G Y * * *',/,7X,'NO.  THETA',
     1'(DEG)    U (M/SEC)    KST   HL (M)  T (DEG-K)            DIURNAL V
     2ARIATIONS (FRACTIONS OF GIVEN Q)',/,T90,'HORIZONAL',2X,'CURVED',3X
     3,'SPECIAL',2X,'SPECIAL',/,T74,'POINT',5X,'AREA',5X,'LINE',5X,'PATH
     4',5X,'LINE',5X,'PATH')
1060  FORMAT (1H0,'THE NUMBER OF MET CARDS EXCEED 24.')
1070  FORMAT (1H ,I9,'.',F10.0,F10.1,I10,2F10.0,10X,6(F8.4,1X))
1080  FORMAT (///,'* * * C O N C E N T R A T I O N S  A T   R E C E P
     1T O R S * * *',/,5X,'CONCENTRATIONS IN GRAMS PER CUBIC METER',T63,
     2'FROM',6X,'FROM',6X,'FROM',6X,'FROM',/,1X,'HOUR',1X,'RECEPTOR ',3X
     3,'RECEPTOR COORDINATES',4X,'FROM',6X,'FROM',6X,'HORIZONAL',1X,'CUR
     4VED',3X,'SPECIAL',3X,'SPECIAL',/,8X,'NO.',5X,'EAST',4X,'NORTH',3X,
     5'HEIGHT',3X,'POINTS',5X,'AREAS',5X,'LINES',5X,'PATHS',5X,'LINES',5
     6X,'PATHS',5X,'TOTAL',//)
1090  FORMAT (1H ,2X,I2,T9,I2,T14,2(F8.3,1X),F6.2,T43,1P7(E8.3,2X))
1100  FORMAT (1H1,'AVERAGE CONCENTRATIONS FOR',I4,' HOURS.')
C
      END
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POINT

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      SUBROUTINE POINT (M,I,N)
C        POINT CALCULATES HOURLY CONTRATIONS FROM POINT SOURCES.
C        THE FOLLOWING SUBROUTINES ARE CALLED BY POINT.
C          FPLUME--HEIGHT OF FINAL PLUME RISE(BRIGGS).
C          XPLUME--EFFECTIVE PLUME RISE AT A DISTANCE X(BRIGGS).
C          RCONCP--DETERMINES THE RELATIVE CONCENTRATION AT
C                  A RECEPTOR FROM A POINT AT A GIVEN UPWIND
C                  AND CROSSWIND DISTANCE.
C         THE FOLLOWING FUNCTIONS ARE CALLED BY POINT.
C           XVY--CALCULATES THE VIRTUAL DISTANCE NECESSARY
C                TO ACCOUNT FOR THE INITIAL CROSSWIND DISPERTION.
C           XVZ--CALCULATES THE VIRTUAL DISTANCE NECESSARY
C                TO ACCOUNT FOR THE INITIAL VERTICAL DISPERTION.
      COMMON /SOP/ QP(31),HPP(31),TSP(31),VSP(31),DP(31),VFP(31),RQP(31)
     1,SQP(31),SYOP(31),SZOP(31),CONP(31,24),DVP(25),IUZP
      COMMON /REC/ RR(31),SR(31),ZR(31)
      COMMON /WEA/ WTHET(25),WU(25),MKST(25),WHL(25),WTA(25),UHGT
      DIMENSION PUZ(6)
      DATA PUZ /0.15,0.15,0.20,0.25,0.40,0.60/
C     QP                POINT SOURCE STRENGTH.           (G/SEC)
C     HPP               PHYSICAL STACK HEIGHT.           (M)
C     TSP               STACK GAS TEMPERATURE.           (DEG K)
C     VSP               STACK GAS VELOCITY.              (M/SEC)
C     DP                STACK INSIDE DIAMETER.           (M)
C     VFP               STACK GAS VOLUME FLOW.           (M**3/SEC)
C     RQP               EAST COORDINATE OF STACK.        (KM)
C     SQP               NORTH COORDINATE OF STACK.       (KM)
C     SYOP              INITIAL SIGMA Y.                 (M)
C     SZOP              INITIAL SIGMA Z.                 (M)
      IWRI=6
      DO 200 NW=1,M
C       DO FOR EACH HOUR.
      THETA=WTHET(NW)
      TR=THETA/57.2958
      SINT=SIN(TR)
      COST=COS(TR)
      U=WU(NW)
      UZ=U
      KST=MKST(NW)
      DTHDZ=0.
      HL=WHL(NW)
      T=WTA(NW)
      PWR=PUZ(KST)
C        CALCULATE FOR ALL SOURCES.
      DO 190 NS=1,I
      KEH=1
      IF (SYOP(NS)) 10,10,20
10    XVYP=0.
      GO TO 30
20    SYON=SYOP(NS)
      XVYP=XVY(SYON,KST)
30    IF (SZOP(NS)) 40,40,50
40    XVZP=0.
```

```
      GO TO 60
50    SZON=SZOP(NS)
      XVZP=XVZ(SZON,KST)
60    CONTINUE
C        CALCULATE FOR ALL RECEPTORS.
      DO 180 NC=1,N
      R=RQP(NS)-RR(NC)
      S=SQP(NS)-SR(NC)
C        DETERMINE DOWNWIND DISTANCE.
      X=S*COST+R*SINT
      IF (X) 180,180,70
C        DETERMINE CROSSWIND DISTANCE
70    Y=S*SINT-R*COST
      GO TO (80,140), KEH
C        ESTIMATE PLUME RISE USING BRIGGS'.
80    IF (TSP(NS)-T) 90,100,100
90    WRITE (IWRI,210) NS
      CALL EXIT
100   GO TO (120,110), IUZP
110   UZ=U*(HPP(NS)/UHGT)**PWR
      IF (HPP(NS).GT.200.) UZ=U*(200./UHGT)**PWR
      IF (UZ.LT.1.) UZ=1.
120   CALL FPLUME (HF,DISTF,F,DELHF,HPP(NS),TSP(NS),VSP(NS),DP(NS),VFP(N
     1S),KST,UZ,DTHDZ,T)
      KEH=2
      IF (X-DISTF) 160,130,130
130   H=HF
      GO TO 170
140   IF (X-DISTF) 160,150,150
150   H=HF
      GO TO 170
160   CALL XPLUME (HX,F,DELHF,HPP(NS),UZ,X)
      H=HX
C        ESTIMATE RELATIVE CONCENTRATION (CHI*U/Q).
170   XZ=X+XVZP
      XY=X+XVYP
      CALL RCONCP (ZR(NC),H,HL,XZ,XY,Y,KST,AN,NDUM,SY,SZ,RC)
      CONP(NC,NW)=CONP(NC,NW)+RC*QP(NS)*DVP(NW)/UZ
180   CONTINUE
190   CONTINUE
200   CONTINUE
      RETURN
C
210   FORMAT (1H0,'NO COMPUTATIONS ARE ATTEMPTED AS SOURCE',I3,'HAS A ST
     1ACK GAS TEMPERATURE LESS THAN THE AMBIENT AIR TEMPERATURE.')
C
      END
```

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AREA

```
      SUBROUTINE AREA (NHR,NQ,NR,PIN)
C        AREA CALCULATES HOURLY CONCENTRATIONS FROM
C        AREA SOURCES.
C        THE FOLLOWING SUBROUTINES ARE CALLED BY AREA.
C          PGSIG--CALCULATES SIGMA Y,AND SIGMA Z,FROM
C                  THE STABILITY AND DOWNWIND DISTANCE.
C          RCONCA--CALCULATES CHI*U/Q,RELATIVE CONCENTRATION
C                  NORMALIZED FOR WIND SPEED FOR A RECEPTOR
C                  DOWNWIND OF A CROSSWIND INFINITE LINE SOURCE.
      COMMON /SOA/ QA(31),HQ(31),RQ(31),SQ(31),DEST(31),DNOR(31),CONA(31
     1,24),DVA(25),IUZA
      COMMON /REC/ RR(31),SR(31),ZR(31)
      COMMON /WEA/ WTHET(25),WU(25),MKST(25),WHL(25),WTA(25),UHGT
      DIMENSION GA(78), RA(4), SA(4), XL(4), PUZ(6)
C        GA ARE VALUES OF THE CUMULATIVE NORMAL DISTRIBUTION IN INCREMEN
C          OF 0.1 S.
      DATA GA /.0,.0001,.0001,.0002,.0002,.0003,.0005,.0007,.0010,.0013,
     1.0019,.0026,.0035,.0047,.0062,.0092,.0107,.0139,.0179,.0228,.0287,
     2.0359,.0446,.0548,.0668,.0808,.0968,.1151,.1357,.1587,.1841,.2119,
     3.2420,.2743,.3085,.3446,.3821,.4207,.4602,.5000,.5398,.5793,.6179,
     4.6554,.6915,.7257,.7580,.7881,.8159,.8413,.8643,.8849,.9032,.9192,
     5.9332,.9452,.9554,.9641,.9713,.9772,.9821,.9861,.9893,.9918,.9938,
     6.9953,.9965,.9974,.9981,.9987,.9990,.9993,.9995,.9997,.9998,.9998,
     7.9999,.9999/
      DATA PUZ /0.15,0.15,0.20,0.25,0.40,0.60/
C     QA               AREA SOURCE STRENGTH.               (G/SEC-M**2)
C     HQ               AREA SOURCE HEIGHT.                 (M)
C     RQ               EAST COORDINATE OF S.W. CORNER.     (KM)
C     SQ               NORTH COORDINATE OF S.W. CORNER.    (KM)
C     DEST             EAST-WEST SIZE.                     (KM)
C     DNOR             NORTH-SOUTH SIZE.                   (KM)
C        SL IS THE Y VALUE (SOURCE UNITS) OF THE INTERSECTION OF LINES
C          XUSE AND R
C        RL IS THE X VALUE (SOURCE UNITS) OF THE INTERSECTION OF LINES
C          XUSE AND S
      SL(R)=((XUSE-((R-RREC)*SINT))/COST)+SREC
      RL(S)=((XUSE-((S-SREC)*COST))/SINT)+RREC
C        X IS THE UPWIND DISTANCE (SOURCE UNITS) OF SOURCE AT (R,S)
C          FROM RECEPTOR AT (RPS,SPS)
C        Y IS THE CROSSWIND DISTANCE (SOURCE UNITS) OF SOURCE AT (R,S)
C          FROM RECEPTOR AT (RPS,SPS)
      X(R,S)=(R-RREC)*SINT+(S-SREC)*COST
      Y(R,S)=(S-SREC)*SINT-(R-RREC)*COST
      IWRI=6
C        DN IS NUMBER USED TO DETERMINE X (UPWIND FROM RECEPTOR) STEP
C          SIZE.
      IDN=10
      DN=IDN
      DO 680 NW=1,NHR
      THETA=WTHET(NW)
      T=THETA/57.2958
C        T IS WIND DIRECTION (RADIANS)
      SINT=SIN(T)
      COST=COS(T)
      U=WU(NW)
      UZ=U
      KST=MKST(NW)
      HL=WHL(NW)
      PWR=PUZ(KST)
      DO 670 NS=1,NQ
C        DETERMINE FOUR BOUNDARIES OF AREA SOURCE. (IN SOURCE UNITS)
      RB1=RQ(NS)
      RB2=RB1+DEST(NS)
      SB3=SQ(NS)
      SB4=SB3+DNOR(NS)
      Q=QA(NS)
      H=HQ(NS)
      GO TO (20,10), IUZA
10    UZ=U*(H/UHGT)**PWR
      IF (H.GT.200.) UZ=U*(200./UHGT)**PWR
      IF (UZ.LT.1.0) UZ=1.0
20    DO 660 NC=1,NR
      RREC=RR(NC)
      SREC=SR(NC)
      Z=ZR(NC)
C        INITIALIZE VARIABLES FOR INTEGRATION PROCEDURE.
      KDN=IDN
      KNT=0
      TEST=1.0
      TOT1=0.
      TOT2=0.
      DMLX=0.
C        KROL IS USED FOR PROGRAM FLOW CONTROL (SEE STEP 590).
      KROL=1
C        DETERMINE UPWIND DISTANCE OF EACH SOURCE CORNER FROM RECEPTOR.
      XL(1)=X(RB1,SB3)
      XL(2)=X(RB1,SB4)
      XL(3)=X(RB2,SB3)
      XL(4)=X(RB2,SB4)
C        NEXT 8 STATEMENTS DETERMINE MAX AND MIN X (UPWIND) DISTANCES
C         OF SOURCE CORNERS.
      XMAX=XL(1)
      XMIN=XL(1)
      DO 60 L=2,4
      IF (XMAX-XL(L)) 30,40,40
30    XMAX=XL(L)
40    IF (XMIN-XL(L)) 60,60,50
50    XMIN=XL(L)
60    CONTINUE
      IF (XMAX) 660,660,70
C        NO PART OF AREA SOURCE IS UPWIND OF RECEPTOR (660)
C        DETERMINE LIMITS FOR X ITERATION. (IN SOURCE UNITS.)
70    IF (XMIN) 80,90,90
80    XMIN=0.
C        DELX IS INTEGRATION X WIDTH(SOURCE UNITS) DMLX IS SAME(METERS).
90    DELX=(XMAX-XMIN)/DN
```

```
      DMLX=DELX*1000.
C        XUSE IS THE CURRENT VALUE OF UPWIND DISTANCE FROM THE RECEPTOR
C         FOR THIS CALC. OF CONC. (A NUMBER OF ITERATIONS ARE DONE FOR
C         THE TRAPEZOIDAL INTEGRATION.)
      XUSE=XMIN
C        JDN IS CONTROL FOR PROPER INCLUSION OF FIRST AND LAST TERMS OF
C         TRAPEZOIDAL INTEGRATION.
      JDN=0
100   TOT=0.
C        DETERMINE TWO LOCI.(IN SOURCE UNITS) TO 215 + 1
      IF (XUSE) 510,560,110
110   I=0
      IF (COST+0.0001) 130,120,120
120   IF (COST-0.0001) 160,160,130
130   S1=SL(RB1)
      IF (S1-SB3) 160,140,140
140   IF (S1-SB4) 150,150,160
150   I=I+1
      RA(I)=RB1
      SA(I)=S1
160   IF (SINT+0.0001) 180,170,170
170   IF (SINT-0.0001) 210,210,180
180   R3=RL(SB3)
      IF (R3-RB1) 210,190,190
190   IF (R3-RB2) 200,200,210
200   I=I+1
      RA(I)=R3
      SA(I)=SB3
      IF (I-2) 210,330,210
210   IF (COST+0.0001) 230,220,220
220   IF (COST-0.0001) 260,260,230
230   S2=SL(RB2)
      IF (S2-SB3) 260,240,240
240   IF (S2-SB4) 250,250,260
250   I=I+1
      RA(I)=RB2
      SA(I)=S2
      IF (I-2) 260,330,260
260   IF (SINT+0.0001) 280,270,270
270   IF (SINT-0.0001) 310,310,280
280   R4=RL(SB4)
      IF (R4-RB1) 310,290,290
290   IF (R4-RB2) 300,300,310
300   I=I+1
      RA(I)=R4
      SA(I)=SB4
310   CONTINUE
      IF (I-2) 550,330,320
320   IERR=215
      GO TO 520
C        DETERMINE CROSSWIND DISTANCE OF THE TWO LOCI.
330   RDUM=RA(1)
      SDUM=SA(1)
      YA=Y(RDUM,SDUM)
      RDUM=RA(2)
      SDUM=SA(2)
      YB=Y(RDUM,SDUM)
C        YA AND YB IN SOURCE UNITS.
      XDUM=XUSE
C        XDUM IS UPWIND DISTANCE (IN KM.).
C        FIND DISPERSION PARAMETER VALUES FOR THIS DISTANCE.
      CALL PGSIG (XDUM,XDUM,KST,SY,SZ)
C        EXPRESS THE CROSSWIND DISTANCE (Y) IN NORMAL DISTRIBUTION
C         DEVIATES. (SMAX AND SMIN)
      IF (YA-YB) 350,550,340
340   SMAX=YA*1000./SY
      SMIN=YB*1000./SY
      GO TO 360
350   SMAX=YB*1000./SY
      SMIN=YA*1000./SY
C        DETERMINE THE CUMULATIVE VALUE OF THE NORMAL DIST. FOR EACH S.
360   IF (SMAX+3.8) 550,550,370
370   IF (SMIN-3.8) 380,550,550
380   IF (SMAX-3.8) 400,400,390
390   CFMAX=1.0
      GO TO 410
400   SSD=SMAX*10.+40.
      ISD=SSD
      SSO=ISD
      CFMAX=GA(ISD)+(SSD-SSO)*(GA(ISD+1)-GA(ISD))
410   IF (SMIN+3.8) 420,420,430
420   CFMIN=0.0
      GO TO 440
430   SSD=SMIN*10.+40.
      ISD=SSD
      SSO=ISD
      CFMIN=GA(ISD)+(SSD-SSO)*(GA(ISD+1)-GA(ISD))
440   CONTINUE
C        DETERMINE THE AREA (CFM) OF THE NORMAL DIST. BETWEEN SMIN AND
C         SMAX.
      CFM=CFMAX-CFMIN
      IF (CFM) 460,450,470
450   CWI=0.
      GO TO 480
460   IERR=405
      GO TO 520
C        DETERMINE THE CROSS-WIND INTEGRATED CONCENTRATION FOR THIS X.
470   CALL RCONCA (Z,H,HL,XDUM,KST,AN,M,SZ,CWI)
C        CWI IS THE CONCENTRATION FROM AN INFINITE LINE SOURCE
C         IN SECONDS PER SQUARE METER.
480   CONTINUE
      GO TO (490,540), KROL
C        STATEMENTS 490-530 PROVIDE FOR ADDITION OF THE TERMS IN THE
C         FORMULA FOR TRAPEZOIDAL INTEGRATION THAT CORRESPOND TO THE
C         ENDPOINTS OF THE INTEGRATION.
490   IF (XUSE-XMIN) 510,530,500
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500   IF (JDN-KDN) 540,530,510
510   IERR=430
      GO TO 520
520   WRITE (IWRI,690) IERR
      CALL EXIT
530   CWI=0.5*CWI
C        TOT IS A SUBTOTAL OF INTEGRATION TERMS FOR CURRENT INTEGRATION
C          (SEC/METER**2) ADJUSTED FOR THE FINITE LENGTH OF SOURCE.
540   TOT=TOT+CWI*CFM
C             JDN = KDN TERMINATES THIS INTEGRATION APPROXIMATION.
550   IF (JDN-KDN) 560,570,580
560   XUSE=XUSE+DELX
      JDN=JDN+1
      GO TO 110
570   IF (TOT) 580,660,590
580   IERR=475
      GO TO 520
590   GO TO (600,610), KROL
C        PROGRAM FLOW REACHES 600 ONLY ON FIRST INTEGRATION ATTEMPT.
600   TOT1=TOT*DMLX
      JDN=1
      KNT=2
      XUSE=XMIN+DELX/2.
      KROL=2
      GO TO 100
610   TOT2=TOT1/2.+(TOT*DMLX)/2.
C        TOT1 IS PREVIOUS ESTIMATE OF INTEGRATION (SEC/METER).
C        TOT2 IS CURRENT ESTIMATE OF INTEGRATION (SEC/METER).
      TEST=ABS(TOT2-TOT1)/TOT2
C        CHECK PRECISION OF INTEGRATIONS AGAINST DESIRED VALUE.
      IF (TEST-PIN) 650,650,620
620   IF (KNT-10) 640,640,630
630   WRITE (IWRI,700) TOT1,TOT2
      IERR=500
      GO TO 520
640   DELX=DELX/2.
      XUSE=XMIN+DELX/2.
      DMLX=DMLX/2.
      TOT1=TOT2
      KNT=KNT+1
      JDN=1
      KDN=2*KDN
C        RETURN TO CALCULATE ADDITIONAL VALUES FOR X DISTANCE
C          MIDWAY BETWEEN X DISTANCES USED FOR LAST ITERATION.
      GO TO 100
650   CONTINUE
      CONA(NC,NW)=CONA(NC,NW)+TOT2*Q*DVA(NW)/UZ
660   CONTINUE
670   CONTINUE
680   CONTINUE
      RETURN
C
690   FORMAT (1H0,'ERROR AT',I5)
700   FORMAT (1H0,'INTERVAL HAS BEEN HALVED 10 TIMES',2E15.8)
C
      END
```

HRZLN

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      SUBROUTINE HRZLN (NHR,NQ,NR,PIN)
C        HRZLN CALCULATES HOURLY CONCENTRATIONS FROM
C        MULTI-LANE HORIZONAL LINE SOURCES.
C        THE FOLLOWING SUBROUTINES ARE CALLED BY HRZLN.
C          RCONCP--DETERMINES THE RELATIVE CONCENTRATION AT
C                  A RECEPTOR FROM A POINT AT A GIVEN UPWIND
C                  AND CROSSWIND DISTANCE.
C         THE FOLLOWING FUNCTIONS ARE CALLED BY HRZLN.
C           XVY--CALCULATES THE VIRTUAL DISTANCE NECESSARY
C                TO ACCOUNT FOR THE INITIAL CROSSWIND DISPERTION.
C           XVZ--CALCULATES THE VIRTUAL DISTANCE NECESSARY
C                TO ACCOUNT FOR THE INITIAL VERTICAL DISPERTION.
      COMMON /SOL/ QLN(31),HLN(31),RAQ(31),SAQ(31),RBQ(31),SBQ(31),SYO(3
     11),SZO(31),CONLH(31,24),DVH(25),IUZR
      COMMON /REC/ RR(31),SR(31),ZR(31)
      COMMON /WEA/ WTHET(25),WU(25),MKST(25),WHL(25),WTA(25),UHGT
      DIMENSION XST(11), YST(11), PUZ(6)
      DATA PUZ /0.15,0.15,0.20,0.25,0.40,0.60/
C     HLN                     LINE SOURCE HEIGHT           (M)
C     NL                      NO. OF LINES IF MULTI-LINE   (DIMENSIONLESS
C     RAQ                     EAST  COORDINATE, POINT A    (KM)
C     SAQ                     NORTH COORDINATE, POINT A    (KM)
C     RBQ                     EAST  COORDINATE, POINT B    (KM)
C     SBQ                     NORTH COORDINATE, POINT B    (KM)
C     SYO                     INITIAL SIGMA Y              (M)
C     SZO                     INITIAL SIGMA Z              (M)
C     WT                      TOTAL WIDTH                  (M)
C     WM                      WIDTH OF MEDIAN              (M)
C     QLT(1)                  LINE SOURCE STRENGTH         (G/SEC-M)
C     QLT(2)                   ONE FOR EACH OF ANL SOURCES.   ,,
C       .                       ORDERING IS FIRST SOURCE      ,,
C       .                        STRENGTH IS FOR LEFT-MOST    ,,
C       .                         LINE WHEN LOOKING FROM      ,,
C     QLT(NL)                      POINT A TO POINT B         ,,
      X(R,S)=(R-RREC)*SINT+(S-SREC)*COST
C        X IS UPWIND DISTANCE OF R,S FROM RREC,SREC
      Y(R,S)=(S-SREC)*SINT-(R-RREC)*COST
C        Y IS CROSSWIND DISTANCE OF R,S FROM RREC,SREC
      DO 940 NW=1,NHR
      THETA=WTHET(NW)
      TR=THETA/57.2958
      SINT=SIN(TR)
      COST=COS(TR)
      U=WU(NW)
      UZ=U
      KST=MKST(NW)
      HL=WHL(NW)
      PWR=PUZ(KST)
      DO 930 NS=1,NQ
      R1=RAQ(NS)
      S1=SAQ(NS)
      R2=RBQ(NS)
      S2=SBQ(NS)
      QL=QLN(NS)
      H=HLN(NS)
      GO TO (20,10), IUZH
10    UZ=U*(H/UHGT)**PWR
      IF (H.GT.200.) UZ=U*(200./UHGT)**PWR
      IF (UZ.LT.1.0) UZ=1.0
20    IF (SYO(NS)) 40,30,40
30    XVYL=0.
      GO TO 50
40    SYON=SYO(NS)
      XVYL=XVY(SYON,KST)
50    IF (SZO(NS)) 70,60,70
60    XVZL=0.
      GO TO 80
70    SZON=SZO(NS)
      XVZL=XVZ(SZON,KST)
80    CONTINUE
      DO 920 NC=1,NR
      RREC=RR(NC)
      SREC=SR(NC)
      Z=ZR(NC)
      X1=X(R1,S1)
      X2=X(R2,S2)
      IF (X1) 90,110,110
90    IF (X2) 100,110,110
100   RC=0.
      GO TO 920
110   DELR=R2-R1
      DELS=S2-S1
      Y1=Y(R1,S1)
      Y2=Y(R2,S2)
      IF (Y1-Y2) 120,420,120
C        IF Y1 = Y2, LINE SOURCE IS PARALLEL TO UPWIND AZIMUTH FROM RECE
120   IF (COST+0.0001) 190,130,130
130   IF (COST-0.0001) 140,140,190
140   IF (DELR+0.0001) 170,150,150
150   IF (DELR-0.0001) 160,160,170
160   SLOC=SREC
      RLOC=R1
      GO TO 310
170   SLP=DELS/DELR
      IF (SLP) 180,420,180
180   SLOC=SREC
      RLOC=(SLOC-S1)/SLP+R1
      GO TO 310
190   IF (SINT+0.0001) 240,200,200
200   IF (SINT-0.0001) 210,210,240
210   IF (DELR+0.0001) 230,220,220
220   IF (DELR-0.0001) 420,420,230
230   SLP=DELS/DELR
      RLOC=RREC
      SLOC=SLP*(RLOC-R1)+S1
      GO TO 310
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240   IF (DELR+0.0001) 270,250,250
250   IF (DELR-0.0001) 260,260,270
260   RLOC=R1
      SLOC=(RLOC-RREC)*COST/SINT+SREC
      GO TO 310
270   IF (DELS+0.0001) 300,280,280
280   IF (DELS-0.0001) 290,300,300
290   SLOC=S1
      RLOC=(SLOC-SREC)*SINT/COST+RREC
      GO TO 310
300   TATH=SINT/COST
C        TATH IS TANGENT (THETA)
      SLP=DELS/DELR
C        SLP IS SLOPE OF LINE SOURCE.
      RLOC=(RREC/TATH+S1-SLP*R1-SREC)/(1/TATH-SLP)
      SLOC=(RLOC-RREC)/TATH+SREC
C        RLOC, SLOC IS LOCUS OF LINE THROUGH LINE SOURCE AND UPWIND VECT
310   XLOC=X(RLOC,SLOC)
      IF (XLOC) 420,420,320
C        XLOC IS POSITIVE IF LOCUS IS UPWIND.
320   IF (S2-S1) 330,330,340
330   SMAX=S1
      SMIN=S2
      GO TO 350
340   SMAX=S2
      SMIN=S1
350   IF (R2-R1) 360,360,370
360   RMAX=R1
      RMIN=R2
      GO TO 380
370   RMAX=R2
      RMIN=R1
C        SEE IF UPWIND LOCUS IS ON LINE SOURCE.
380   IF (RLOC-RMIN) 420,390,390
390   IF (RMAX-RLOC) 420,400,400
400   IF (SLOC-SMIN) 420,410,410
410   IF (SMAX-SLOC) 420,430,430
420   INDIC=1
C        INDIC =1 FOR NO LOCUS ON LINE SOURCE.
      XA=X1
      YA=Y1
      XB=X2
      YB=Y2
      GO TO 440
430   INDIC=2
C        INDIC =2 FOR LOCUS ON LINE SOURCE.
      XA=X1
      YA=Y1
      XB=XLOC
      YB=0.
440   DISX=XB-XA
      DISY=YB-YA
      DISI=SQRT(DISX*DISX+DISY*DISY)
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C         DISI IS LENGTH(KM) OF LINE CONSIDERED.
      IF (DISI) 460,450,460
 450  CURR=0.
      GO TO 860
 460  DDI=DISI*1000./20.
C         ONE-HALF IS INCLUDED IN THE 20.
C         DDI IS ONE-HALF TIMES 1/10 OF DISI (M).
      DX=DISX/10.
      DY=DISY/10.
      PREV=0.
      KNTRL=1
      XI=XA
      YI=YA
      KNT=0
      DO 580 I=1,11
C         STORE EACH XI,YI.
      XST(I)=XI
      YST(I)=YI
      IF (XST(I)) 470,470,480
 470  RC=0.
      GO TO 490
 480  XZ=XI+XVZL
      XY=XI+XVYL
      CALL RCONCP (Z,H,HL,XZ,XY,YI,KST,AN,M,SY,SZ,RC)
 490  GO TO (500,540), KNTRL
C         IF RC IS ZERO, CONTINUE UNTIL RC IS POSITIVE.
 500  IF (RC) 570,570,510
 510  IF (I-1) 520,520,530
 520  KNTRL=2
      GO TO 560
C         RESET POINT A TO LAST ONE PREVIOUS.
 530  XA=XST(I-1)
      YA=YST(I-1)
      KNTRL=2
      GO TO 560
 540  IF (RC) 550,550,560
C         RESET POINT B IF REACH ZERO CONCENTRATION.
 550  XB=XI
      YB=YI
      GO TO 590
 560  KNT=KNT+1
 570  XI=XI+DX
      YI=YI+DY
 580  CONTINUE
 590  IF (KNT) 610,610,600
 600  IF (KNT-6) 440,440,650
C         IF GET TO 610, CONC. FROM THIS SEGMENT IS 0.
 610  GO TO (620,630,640), INDIC
 620  RC=0.
      GO TO 920
 630  FIRST=0.
      GO TO 890
 640  RC=FIRST
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      GO TO 910
650   CONTINUE
C        DO ANOTHER TRAPEZOIDAL INTEGRATION FROM A TO B IN TEN STEPS.
C        IT IS LIKELY THAT A TO B HAVE BEEN REDEFINED.
      DISX=XB-XA
      DISY=YB-YA
      DISI=SQRT(DISX*DISX+DISY*DISY)
C        DISI IS DISTANCE(KM) FROM A TO B
      DELD=DISI*100.
C        DELD IS 1/10 DISI IN METERS.
      DX=DISX/10.
      DY=DISY/10.
      SUM=0.
      XDUM=XA
      YDUM=YA
      IF (XDUM) 660,660,670
660   RC=0.
      GO TO 680
670   XZ=XDUM+XVZL
      XY=XDUM+XVYL
      CALL RCONCP (Z,H,HL,XZ,XY,YDUM,KST,AN,M,SY,SZ,RC)
680   SUM=SUM+RC/2.
      DO 710 I=1,9
      XDUM=XDUM+DX
      YDUM=YDUM+DY
      IF (XDUM) 690,690,700
690   RC=0.
      GO TO 710
700   XZ=XDUM+XVZL
      XY=XDUM+XVYL
      CALL RCONCP (Z,H,HL,XZ,XY,YDUM,KST,AN,M,SY,SZ,RC)
710   SUM=SUM+RC
      XDUM=XDUM+DX
      YDUM=YDUM+DY
      IF (XDUM) 720,720,730
720   RC=0.
      GO TO 740
730   XZ=XDUM+XVZL
      XY=XDUM+XVYL
      CALL RCONCP (Z,H,HL,XZ,XY,YDUM,KST,AN,M,SY,SZ,RC)
740   SUM=SUM+RC/2.
C        INTEGRATED VALUE IS CURR.
      CURR=SUM*DELD
      ILIM=10
750   PREV=CURR
C        EVALUATE FOR POINTS IN BETWEEN THOSE ALREADY EVALUATED.
      DELD=DELD/2.
      XDUM=XA+DX/2.
      YDUM=YA+DY/2.
      DO 790 I=1,ILIM
      IF (XDUM) 760,760,770
760   RC=0.
      GO TO 780
```

```
  770 XZ=XDUM+XVZL
      XY=XDUM+XVYL
      CALL RCONCP (Z,H,HL,XZ,XY,YDUM,KST,AN,M,SY,SZ,RC)
C        NOTE ADD THESE TO RC'S FOUND ABOVE.
  780 SUM=SUM+RC
      XDUM=XDUM+DX
  790 YDUM=YDUM+DY
      CURR=SUM*DELD
      TEST=ABS((CURR-PREV)/CURR)
C        IF WITHIN PIN OF LAST VALUE (PREV), CONSIDER THIS AS FINAL VALU
      IF (TEST-PIN) 860,800,800
  800 ILIM=ILIM*2
      PREV=CURR
C        EVALUATE POINTS IN BETWEEN.
      DELD=DELD/2.
      DX=DX/2.
      DY=DY/2.
      XDUM=XA+DX/2.
      YDUM=YA+DY/2.
      DO 840 I=1,ILIM
      IF (XDUM) 810,810,820
  810 RC=0.
      GO TO 830
  820 XZ=XDUM+XVZL
      XY=XDUM+XVYL
      CALL RCONCP (Z,H,HL,XZ,XY,YDUM,KST,AN,M,SY,SZ,RC)
  830 SUM=SUM+RC
      XDUM=XDUM+DX
  840 YDUM=YDUM+DY
      CURR=SUM*DELD
      TEST=ABS((CURR-PREV)/CURR)
      IF (TEST-PIN) 860,850,850
  850 ILIM=ILIM*2
      DX=DX/2.
      DY=DY/2.
      GO TO 750
C        AT 860 HAVE FINAL VALUE OF INTEGRATION IN CURR.
  860 GO TO (870,880,900), INDIC
  870 RC=CURR
      GO TO 910
  880 FIRST=CURR
  890 INDIC=3
      XA=XLOC
      YA=0.
      XB=X2
      YB=Y2
      GO TO 440
  900 RC=FIRST+CURR
  910 CONLH(NC,NW)=CONLH(NC,NW)+RC*QL*DVH(NW)/UZ
  920 CONTINUE
  930 CONTINUE
  940 CONTINUE
      RETURN
C
      END
```

CRVLN

```
      SUBROUTINE CRVLN (NHR,NQ,NR,PIN)
C        CRVLN CALCULATES HOURLY CONCENTRATIONS FROM
C        MULTI-LANE CURVED PATH SOURCES.
C        THE FOLLOWING SUBROUTINES ARE CALLED BY CRVLN.
C          CURLIN--CALCULATES THE INTERSECTION OF THE
C                   LINE FORMED BY THE WIND DIRECTION AND
C                   RECEPTOR COORDINATES AND THE CIRCLE
C                   DETERMINED FROM POINTS A,B,C.
C          RCONCP--DETERMINES THE RELATIVE CONCENTRATION AT
C                  A RECEPTOR FROM A POINT AT A GIVEN UPWIND
C                  AND CROSSWIND DISTANCE.
C         THE FOLLOWING FUNCTIONS ARE CALLED BY CRVLN.
C           XVY--CALCULATES THE VIRTUAL DISTANCE NECESSARY
C                TO ACCOUNT FOR THE INITIAL CROSSWIND DISPERTION.
C           XVZ--CALCULATES THE VIRTUAL DISTANCE NECESSARY
C                TO ACCOUNT FOR THE INITIAL VERTICAL DISPERTION.
C           ANGARC--DETERMINES THE APPROPRIATE ARCTAN(M/N)
C                   WITH THE RESULTING ANGLE BETWEEN 0 AND
C                   360 DEGREES.
C           DIFANG--DETERMINES THE DIFFERENCE BETWEEN TWO ANGLES.
C                   THE RESULTING ANGLE IS BETWEEN 0 AND 360 DEGREES.
      COMMON /SOCP/ QLNS(31),HLNS(31),RBQS(31),SBQS(31),RMQS(31),SMQS(31
     1),REQS(31),SEQS(31),SIYO(31),SIZO(31),CONCLN(31,24),DDVH(31),IUZC,
     2RADIUS(31),NLANE(31)
      COMMON /REC/ RR(31),SR(31),ZR(31)
      COMMON /WEA/ WTHET(25),WU(25),MKST(25),WHL(25),WTA(25),UHGT
      DIMENSION PUZ(6), RRR(11), SSS(11), DIR(11), ARC(5), XANG(5)
      DATA PUZ /0.15,0.15,0.20,0.25,0.40,0.60/
C     QLNS  PATH SOURCE STRENGTH FOR EACH LANE       (G/SEC-M)
C     HLNS  HEIGHT OF THE PATH SOURCE                (M)
C     RBQS  EAST COORDINATE,POINT A                  (KM)
C     SBQS  NORTH COORDINATE,POINT A                 (KM)
C     RMQS  EAST COORDINATE,POINT B                  (KM)
C     SMQS  NORTH COORDINATE,POINT B                 (KM)
C     REQS  EAST COORDINATE,POINT C                  (KM)
C     SEQS  NORTH COORDINATE,POINT C                 (KM)
C     SIYO  INITIAL SIGMA Y                          (M)
C     SIZO  INITIAL SIGMA Z                          (M)
C     CONCLN  CONCENTRATION                          (G/M**3)
C     DDVH  DIURNAL VARIATION,CURVED PATH SOURCE     (DIMENSIONLESS)
C     IUZC  WIND INCREASE WITH HEIGHT                (DIMENSIONLESS)
C     RR  EAST COORDINATE OF RECEPTOR                (KM)
C     SR  NORTH COORDINATE OF RECEPTOR               (KM)
C     ZR    HEIGHT OF RECEPTOR ABOVE GROUND          (M)
C     WTHET  WIND DIRECTION                          (DEG AZIMUTH)
C     WU  WIND SPEED                                 (M/SEC)
C     MKST  STABILITY CLASS                          (DIMENSIONLESS)
C     WHL  MIXING HEIGHT                             (M)
C     WTA  AMBIENT AIR SURFACE TEMP.                 (DEG K)
C     WP   AMBIENT AIR SURFACE PRESSURE              (MB)
      X(R,S)=(R-RREC)*SINT+(S-SREC)*COST
C        X IS UPWIND DISTANCE OF R,S FROM RREC,SREC
      Y(R,S)=(S-SREC)*SINT-(R-RREC)*COST
```

```
C        Y IS CROSSWIND DISTANCE OF R,S FROM RREC,SREC
C        START DO LOOP FOR EACH HOUR.
      DO 460 NW=1,NHR
      NUMC=0
      THETA=WTHET(NW)
      TR=THETA/57.2958
      SINT=SIN(TR)
      COST=COS(TR)
      U=WU(NW)
      UZ=U
      KST=MKST(NW)
      HL=WHL(NW)
      PWR=PUZ(KST)
C        START DO LOOP FOR EACH CURVED PATH.
      DO 460 NS=1,NQ
      RB=RBQS(NS)
      RM=RMQS(NS)
      RE=REQS(NS)
      SB=SBQS(NS)
      SM=SMQS(NS)
      SE=SEQS(NS)
      H=HLNS(NS)
      GO TO (20,10), IUZC
 10   UZ=U*(H/UHGT)**PWR
      IF (H.GT.200.) UZ=U*(200./UHGT)**PWR
      IF (UZ.LT.1.0) UZ=1.0
 20   IF (SIYO(NS)) 40,30,40
 30   XVYL=0.
      GO TO 50
 40   SYON=SIYO(NS)
      XVYL=XVY(SYON,KST)
 50   IF (SIZO(NS)) 70,60,70
 60   XVZL=0.
      GO TO 80
 70   SZON=SIZO(NS)
      XVZL=XVZ(SZON,KST)
 80   CONTINUE
C        THE COORDINATES OF THE CENTER OF THE CIRCLE,
C          DETERMINED FROM THE INTERSECTION OF THE PERPENDICULAR
C          BISECTORS OF CHORDS AB AND BC,AND THE RADIUS OF THE
C          CIRCLE ARE CALCULATED.
      RMID=(RB+RM)/2.
      SMID=(SB+SM)/2.
      RNID=(RM+RE)/2.
      SNID=(SM+SE)/2.
      IF (RM-RB.EQ.0) GO TO 90
      IF (RE-RM.EQ.0) GO TO 100
C        SLO1 IS THE SLOPE OF THE PERPENDICULAR BISECTOR
C        OF CHORD AB.
C        SLO2 IS THE SLOPE OF THE PERPENDICULAR BISECTOR
C        OF CHORD BC.
      SLO1=-((RM-RB)/(SM-SB))
      SLO2=-((RE-RM)/(SE-SM))
```

```
C        RC AND SC ARE THE COORDINATES OF THE CENTER OF THE
C        CIRCLE.
      RC=(SLO1*RMID+SNID-SMID-SLO2*RNID)/(SLO1-SLO2)
      SC=SLO1*(RC-RMID)+SMID
      GO TO 110
90    RC=RMID
      SLO2=-((RE-RM)/(SE-SM))
      SC=SLO2*(RC-RNID)+SNID
      GO TO 110
100   RC=RNID
      SLO1=-((RM-RB)/(SM-SB))
      SC=SLO1*(RC-RMID)+SMID
      GO TO 110
C        RAD IS THE RADIUS OF THE CIRCLE.
110   RAD=SQRT((RC-RB)**2+(SC-SB)**2)
      DELM=RB-RC
      DELN=SB-SC
C        ANGB IS THE DIRECTED ANGLE FROM THE CENTER TO POINT A.
      ANGB=ANGARC(DELM,DELN)
      DELM=RM-RC
      DELN=SM-SC
C        ANGM IS THE DIRECTED ANGLE FROM THE CENTER TO POINT B.
      ANGM=ANGARC(DELM,DELN)
      DELM=RE-RC
      DELN=SE-SC
C        ANGE IS THE DIRECTED ANGLE FROM THE CENTER TO POINT C.
      ANGE=ANGARC(DELM,DELN)
      ANGBE=ABS(DIFANG(ANGB,ANGE))
      ANGBM=ABS(DIFANG(ANGB,ANGM))
      ANGME=ABS(DIFANG(ANGM,ANGE))
      IF (ANGBM.LT.ANGBE.AND.ANGME.LT.ANGBE) GO TO 120
      GAMDEG=360.-ANGBE
      GO TO 130
120   GAMDEG=ANGBM+ANGME
130   A=1.
      IF (GAMDEG.GE.180.) GO TO 140
      BEDEG=DIFANG(ANGE,ANGB)
      IF (BEDEG.LT.0.) A=-1.
      GO TO 150
140   RDEG=ANGB+180.
      RMDEG=DIFANG(ANGM,RDEG)
      REDEG=DIFANG(ANGE,RDEG)
      IF (RMDEG.GE.0..AND.REDEG.LE.0.) A=-1.
150   CONTINUE
      NUMLNE=NLANE(NS)
      NUMC=NUMLNE+NUMC
      NLL=NUMC-NUMLNE+1
      RDI=RAD
      DO 460 NL=NLL,NUMC
      RAD=RDI+RADIUS(NL)
      QL=QLNS(NL)
      DO 460 NC=1,NR
      RREC=RR(NC)
      SREC=SR(NC)
      Z=ZR(NC)
C     CURLIN CALCULATES THE COORDINATES OF ANY UPWIND LOCI ON ARC AB
C     FROM HERE TO STATEMENT 310 THE BEGINNING AND ENDING
C     POINTS,WITH THEIR CORRESPONDING DIRECTIONS,FOR EACH SEGMENT
C     OF THE ARC ARE CALCULATED
      CALL CURLIN (RC,SC,RREC,SREC,Z,RAD,THETA,RL,SL,RL1,SL1,NLOCI)
      IF (NLOCI) 160,170,180
C     NLOCI HAS VALUES OF -1,0,OR 1 FOR:
C     NO UPWIND LOCI ON ARC AB: 1 LOCI ON ARC AB:
C     OR 2 LOCI ON ARC AB
160   XANG(1)=ANGB
      ARC(1)=GAMDEG
      J=1
      GO TO 310
170   K=1
      GO TO 190
180   K=2
190   N=1
      DO 270 KK=1,K
      IF (KK.EQ.2) GO TO 200
      DELM=RL-RC
      DELN=SL-SC
      ANGRL=ANGARC(DELM,DELN)
      RANG=ANGRL
      GO TO 210
200   DELM=RL1-RC
      DELN=SL1-SC
      ANGRL=ANGARC(DELM,DELN)
      RLANG=ANGRL
210   IF (GAMDEG.GT.180..AND.A.GT.0.) GO TO 220
      IF (GAMDEG.GE.180..AND.A.LT.0.) GO TO 230
      IF (GAMDEG.LT.180..AND.A.LT.0.) GO TO 240
      BIN=DIFANG(ANGRL,ANGB)
      IF (BIN.LE.0..OR.BIN.GE.GAMDEG) GO TO 260
      ARC(N)=BIN
      GO TO 250
220   BIN=DIFANG(ANGRL,ANGB)
      IF (BIN.GT.0.) ARC(N)=BIN
      IF (BIN.GT.0.) GO TO 250
      IF (BIN.LE.0.) DIF=(GAMDEG-360.)-BIN
      IF (DIF.LT.0.) GO TO 260
      ARC(N)=BIN+360.
      GO TO 250
230   BIN=DIFANG(ANGRL,ANGB)
      IF (BIN.LT.0.) ARC(N)=BIN
      IF (BIN.LT.0.) GO TO 250
      IF (BIN.GE.0..AND.BIN.LE.360.-GAMDEG) GO TO 260
      ARC(N)=360.-BIN
      GO TO 250
240   BIN=DIFANG(ANGRL,ANGB)
      IF (BIN.GE.0..OR.BIN.LE.-GAMDEG) GO TO 260
      ARC(N)=BIN
      GO TO 250
250   N=N+1
      INDEX=-1
      IF (KK.EQ.2) INDEX=1
      GO TO 270
260   IF (K.NE.1) GO TO 270
      XANG(1)=ANGB
      ARC(1)=GAMDEG
270   CONTINUE
      XANG(1)=ANGB
      IF (N-1.EQ.0) GO TO 300
      IF (N-1.EQ.2) GO TO 280
      ARC(2)=GAMDEG-ABS(ARC(1))
      XANG(2)=RANG
      IF (INDEX.EQ.1) XANG(2)=RLANG
      J=2
      GO TO 310
280   ARC(1)=ABS(ARC(1))
      ARC(2)=ABS(ARC(2))
      IF (ARC(1).GT.ARC(2)) GO TO 290
      ARC(2)=ARC(2)-ARC(1)
      ARC(3)=GAMDEG-ARC(1)-ARC(2)
      XANG(2)=RANG
      XANG(3)=RLANG
      J=3
      GO TO 310
290   AA=ARC(1)
      ARC(1)=ARC(2)
      ARC(2)=AA-ARC(2)
      ARC(3)=GAMDEG-ARC(1)-ARC(2)
      XANG(2)=RLANG
      XANG(3)=RANG
      J=3
      GO TO 310
300   J=1
      ARC(1)=GAMDEG
310   TOTAL=0.
      DO 450 M=1,J
      KNT=0
      NM=0
      LCOUNT=0
C     CHI VALUES ARE CALCULATED FOR 11 POINTS ON THE ARC SEGMENT.
C     THE SEGMENT IS REDUCED IN SIZE UNTIL AT LEAST 7 OF THE 11 CHI
C     VALUES ARE NON-ZERO.
320   DO 350 L=1,11
      DIR(L)=XANG(M)+(A*(L-1)/10.)*ABS(ARC(M))
      IF (DIR(L).GT.360.) DIR(L)=DIR(L)-360.
      IF (DIR(L).LT.0.) DIR(L)=DIR(L)+360.
      DIRRAD=DIR(L)/57.29578
      RRR(L)=RC+RAD*SIN(DIRRAD)
      SSS(L)=SC+RAD*COS(DIRRAD)
      XZ=X(RRR(L),SSS(L))+XVZL
      IF (XZ-XVZL) 350,350,330
```

```
330   XY=X(RRR(L),SSS(L))+XVYL
      YI=Y(RRR(L),SSS(L))
      CALL RCONCP (Z,H,HL,XZ,XY,YI,KST,AN,MI,SY,SZ,CHI)
      IF (CHI) 350,350,340
340   NM=NM+1
C     THE NEXT TWO STEPS DETERMINE THE DIRECTION FROM
C     THE CENTER TO THE NEW STARTING POINT
      IF (L.EQ.1) DIRINT=DIR(L)
      IF (NM.EQ.1.AND.L.GT.1) DIRINT=DIR(L-1)
      IF (L.GT.1.AND.NM.EQ.1) NM=2
      LCOUNT=0
      IF (L.NE.11) LCOUNT=1
350   CONTINUE
      NM=NM+LCOUNT
      IF (NM) 430,430,360
360   IF (NM.GT.7) GO TO 370
      VAR=NM-1
      ARC(M)=ABS(ARC(M))*(VAR/10.)
      XANG(M)=DIRINT
      NM=0
      GO TO 320
C     DO A TRAPEZOIDAL INTEGRATION FROM A TO B IN TEN STEPS.
C     IT IS LIKELY THAT A OR B HAVE BEEN REDEFINED.
370   II=11
      L=1
      KK=1
      SUM=0.
      VAR=NM-1
      ARR=ABS(ARC(M))*(VAR/10.)
C     DELL=1/10 OF THE ARC LENGTH IN METERS
      DELL=((ARR/10.)/57.29578)*RAD*1000.
380   DO 400 I=L,II,KK
      DIV=II-1.
      DIRR=DIRINT+(A*(I-1)/DIV)*ARR
      DIRRAD=DIRR/57.29578
      RRR1=RC+RAD*SIN(DIRRAD)
      SSS1=SC+RAD*COS(DIRRAD)
      XZ=X(RRR1,SSS1)+XVZL
      IF (XZ-XVZL) 400,400,390
390   XY=X(RRR1,SSS1)+XVYL
      YI=Y(RRR1,SSS1)
      CALL RCONCP (Z,H,HL,XZ,XY,YI,KST,AN,MI,SY,SZ,CHI)
      IF (I.EQ.1) Q1=CHI/2.
      IF (I.EQ.II) Q2=CHI/2.
      SUM=SUM+CHI
400   CONTINUE
      KNT=KNT+1
      IF (KNT.GT.1) GO TO 410
      TOTQ=SUM-Q1-Q2
      TOTQ2=TOTQ*DELL
      SUM=0.
      DELL=DELL/2.
      II=21
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CRVLN

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      L=2
      KK=2
      GO TO 380
  410 CONTINUE
      TOTQ=TOTQ+SUM
      TOTQ1=TOTQ*DELL
      TEST=ABS((TOTQ1-TOTQ2)/TOTQ1)
      IF (TEST-PIN) 440,420,420
  420 TOTQ2=TOTQ1
      DELL=DELL/2.
      II=2*II-1
      SUM=0.
      GO TO 380
  430 TOTQ1=0.
  440 CONTINUE
      TOTAL=TOTAL+TOTQ1
  450 CONTINUE
      CONCLN(NC,NW)=CONCLN(NC,NW)+TOTAL*QL*DDVH(NW)/UZ
  460 CONTINUE
      RETURN
C
      END
```

SPCLN

```
      SUBROUTINE SPCLN (NHR,NQ,NR,PIN)
C       S P E C I A L   L I N E   S O U R C E
C       THIS SUBROUTINE DETERMINES CONCENTRATIONS FROM
C       SPECIAL LINE SOURCES.CASES CONSIDERED INCLUDE
C       DIFFERENT HEIGHTS(ABOVE GROUND)OF END POINTS;
C       CONSTANT VELOCITY OF SOURCES ALONG LINE,OR
C       CONSTANT ACCELERATION(LINEAR VELOCITY CHANGE);
C       DECELERATION IS NEGATIVE ACCELERATION,AND
C       VARIATION OF WIND WITH HEIGHT.
C         THE FOLLOWING SUBROUTINES ARE CALLED BY SPCLN.
C        RCONCP--DETERMINES THE RELATIVE CONCENTRATION AT
C                 A RECEPTOR FROM A POINT AT A GIVEN UPWIND
C                 AND CROSSWIND DISTANCE.
C         THE FOLLOWING FUNCTIONS ARE CALLED BY SPCLN.
C           XVY--CALCULATES THE VIRTUAL DISTANCE NECESSARY
C                TO ACCOUNT FOR THE INITIAL CROSSWIND DISPERTION.
C           XVZ--CALCULATES THE VIRTUAL DISTANCE NECESSARY
C                TO ACCOUNT FOR THE INITIAL VERTICAL DISPERTION.
      COMMON /SOLS/ QLS(31),HAS(31),HBS(31),RAS(31),SAS(31),RBS(31),SBS(
     131),SYOS(31),SZOS(31),CONLS(31,24),DVS(25),IUZS,SPDI(31),SPDF(31),
     2TVSL(31),VSSL(31)
      COMMON /REC/ RR(31),SR(31),ZR(31)
      COMMON /WEA/ WTHET(25),WU(25),MKST(25),WHL(25),WTA(25),UHGT
      DIMENSION XST(11), YST(11), HST(11), PUZ(6)
      DATA PUZ /0.15,0.15,0.20,0.25,0.40,0.60/
C     QLS            LINE SOURCE STRENGTH.           (G/SEC)
C     HAS            HEIGHT OF POINT A.              (M)
C     HBS            HEIGHT OF POINT B               (M)
C     RAS            EAST COORDINATE,POINT A.        (KM)
C     SAS            NORTH COORDINATE,POINT A.       (KM)
C     RBS            EAST COORDINATE,POINT B.        (KM)
C     SBS            NORTH COORDINATE,POINT B.       (KM)
C     SPDI           SPEED AT POINT A.               (M/SEC)
C     SPDF           SPEED AT POINT B.               (M/SEC)
C     SYOS           INITIAL SIGMA Y.                (M)
C     SZOS           INITIAL SIGMA Z.                (M)
C     TVSL           VEHICLE VOLUME.                 (VEH/HR)
C     VSSL           GROSS ESTIMATE OF VEH. SIZE.    (M)
      X(R,S)=(R-RREC)*SINT+(S-SREC)*COST
C        X IS UPWIND DISTANCE OF R,S FROM RREC,SREC
      Y(R,S)=(S-SREC)*SINT-(R-RREC)*COST
C        Y IS CROSSWIND DISTANCE OF R,S FROM RREC,SREC
      DISTA(RM,SM,HM)=SQRT((RM-XS)**2.+(SM-YS)**2.+(HM-HGT)**2.)
      DO 1080 NW=1,NHR
C      DO FOR EACH HOUR.
      THETA=WTHET(NW)
      TR=THETA/57.2958
      SINT=SIN(TR)
      COST=COS(TR)
      U=WU(NW)
      UZ=U
      KST=MKST(NW)
      HL=WHL(NW)
```

SPCLN

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      PWR=PUZ(KST)
      DO 1070 NS=1,NQ
C       DO FOR EACH LINE SOURCE.
      R1=RAS(NS)
      S1=SAS(NS)
      R2=RBS(NS)
      S2=SBS(NS)
      QL=QLS(NS)*(TVSL(NS)/3600.)
      SCALV=VSSL(NS)*(TVSL(NS)/3600.)
      H1=HAS(NS)
      HGT=H1*0.001
      H2=HBS(NS)
      DELR=R2-R1
      DELS=S2-S1
      DIST=SQRT(DELR**2+DELS**2)
      DELH=H2-H1
      VI=SPDI(NS)**2
      VF=SPDF(NS)**2
      DELSPD=VF-VI
      DISTOL=SQRT((R2-R1)**2.+(S2-S1)**2.+(H2*0.001-H1*.001)**2.)
      IF (SYOS(NS)) 10,10,20
10    XVYL=0.
      GO TO 30
20    SYON=SYOS(NS)
      XVYL=XVY(SYON,KST)
30    IF (SZOS(NS)) 40,40,50
40    XVZL=0.
      GO TO 60
50    SZON=SZOS(NS)
      XVZL=XVZ(SZON,KST)
60    CONTINUE
      DO 1060 NC=1,NR
C       DO FOR EACH RECEPTOR.
      RREC=RR(NC)
      SREC=SR(NC)
      Z=ZR(NC)
      X1=X(R1,S1)
      XS=X1
      X2=X(R2,S2)
      IF (X1) 70,70,80
70    IF (X2) 1060,1060,80
80    Y1=Y(R1,S1)
      YS=Y1
      Y2=Y(R2,S2)
C       IF Y1 AND Y2 ARE BOTH POSITIVE OR BOTH NEGATIVE NO LOCUS
C       ON THE LINE SOURCE ,GO TO 390.
      IF (Y1.GE.0.0.AND.Y2.GE.0.0) GO TO 390
      IF (Y1.LE.0.0.AND.Y2.LE.0.0) GO TO 390
C         IF Y1 = Y2, LINE SOURCE IS PARALLEL TO UPWIND AZIMUTH FROM RECE
      IF (DIST) 90,390,90
90    IF (COST+0.0001) 160,100,100
100   IF (COST-0.0001) 110,110,160
110   IF (DELR+0.0001) 140,120,120
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```
C        AT (110) COST APPROX.ZERO,WIND 90 DEG. OR 270.
120     IF (DELR-0.0001) 130,130,140
130     SLOC=SREC
C         AT(130) LINE SOURCE IS NORTH-SOUTH.
        RLOC=R1
        GO TO 280
140     SLP=DELS/DELR
C         AT(140) WIND STILL 90 DEG. OR 270.
        IF (SLP) 150,390,150
C        IF SLP ZERO LINE PARALLEL TO WIND.
150     SLOC=SREC
        RLOC=(SLOC-S1)/SLP+R1
        GO TO 280
160     IF (SINT+0.0001) 210,170,170
C        AT(160) WIND NOT 90 DEG. OR 270.
170     IF (SINT-0.0001) 180,180,210
180     IF (DELR+0.0001) 200,190,190
C        AT(180) WIND 0 DEG. OR 180.
190     IF (DELR-0.0001) 390,390,200
C       GO TO 390 IF LINE SOURCE PARALLEL TO WIND.
200     SLP=DELS/DELR
C         AT(200) WIND 0 DEG. OR 180 DEG. AND DELR IS NOT ZERO.
        RLOC=RREC
        SLOC=SLP*(RLOC-R1)+S1
        GO TO 280
210     IF (DELR+0.0001) 240,220,220
C         AT(210) WIND NOT FROM 4 CARDINAL DIRECTIONS.
220     IF (DELR-0.0001) 230,230,240
230     RLOC=R1
C         AT(230) LINE SOURCE IS NORTH-SOUTH.
        SLOC=(RLOC-RREC)*COST/SINT+SREC
        GO TO 280
240     IF (DELS+0.0001) 270,250,250
250     IF (DELS-0.0001) 260,270,270
260     SLOC=S1
C         AT(260) LINE SOURCE IS EAST-WEST.
        RLOC=(SLOC-SREC)*SINT/COST+RREC
        GO TO 280
270     TATH=SINT/COST
C         AT(270) GENERAL CASE,WIND NOT FROM CARDINAL DIRECTION
C         AND LINE SOURCE NOT EAST-WEST NOR NORTH-SOUTH.
C           TATH IS TANGENT (THETA)
        SLP=DELS/DELR
C           SLP IS SLOPE OF LINE SOURCE.
        RLOC=(RREC/TATH+S1-SLP*R1-SREC)/(1/TATH-SLP)
        SLOC=(RLOC-RREC)/TATH+SREC
C           RLOC, SLOC IS LOCUS OF LINE THROUGH LINE SOURCE AND UPWIND VECT
280     XLOC=X(RLOC,SLOC)
        IF (XLOC) 390,390,290
C           XLOC IS POSITIVE IF LOCUS IS UPWIND.
290     IF (S2-S1) 300,300,310
300     SMAX=S1
        SMIN=S2
```

```
      GO TO 320
310   SMAX=S2
      SMIN=S1
320   IF (R2-R1) 330,330,340
330   RMAX=R1
      RMIN=R2
      GO TO 350
340   RMAX=R2
      RMIN=R1
C        SEE IF UPWIND LOCUS IS ON LINE SOURCE.
350   IF (RLOC-RMIN) 390,360,360
360   IF (RMAX-RLOC) 390,370,370
370   IF (SLOC-SMIN) 390,380,380
380   IF (SMAX-SLOC) 390,400,400
390   INDIC=1
C        INDIC =1 FOR NO LOCUS ON LINE SOURCE.
      XA=X1
      YA=Y1
      HA=H1
      XB=X2
      YB=Y2
      HB=H2
      GO TO 410
400   INDIC=2
C        INDIC =2 FOR LOCUS ON LINE SOURCE.
      XA=X1
      YA=Y1
      HA=H1
      XB=XLOC
      YB=0.
      RDUM=RLOC-R1
      SDUM=SLOC-S1
      DDUM=SQRT(RDUM*RDUM+SDUM*SDUM)
      HB=(DDUM/DIST)*(H2-H1)+H1
      HLOC=HB
410   DISX=XB-XA
      DISY=YB-YA
      DISH=0.001*(HB-HA)
      DISI=SQRT(DISX**2+DISY**2+DISH**2)
C        DISI IS LENGTH(KM) OF LINE CONSIDERED.
      IF (DISI) 420,420,430
420   CURR=0.
      GO TO 1000
430   DDI=DISI*1000./20.
C        ONE-HALF IS INCLUDED IN THE 20.
C        DDI IS ONE-HALF TIMES 1/10 OF DISI (M).
      DX=DISX/10.
      DY=DISY/10.
      DH=(HB-HA)/10.
C       DH IS IN METERS.
      PREV=0.
      KNTRL=1
      XI=XA
      YI=YA
      HI=HA
      KNT=0
      DO 570 I=1,11
C        STORE EACH XI,YI.
      XST(I)=XI
      YST(I)=YI
      HST(I)=HI
      IF (XST(I)) 440,440,450
440   RC=0.
      GO TO 480
450   XZ=XI+XVZL
      XY=XI+XVYL
      H=HI
      GO TO (470,460), IUZS
460   UZ=U*(H/UHGT)**PWR
      IF (H.GT.200.) UZ=U*(200./UHGT)**PWR
      IF (UZ.LT.1.0) UZ=1.0
470   CALL RCONCP (Z,H,HL,XZ,XY,YI,KST,AN,M,SY,SZ,RC)
      RC=RC/UZ
      HH=H*0.001
      DIS=DISTA(XI,YI,HH)/DISTOL
      SPEED=SQRT(VI+DELSPD*DIS)
      IF (SPEED.LT.SCALV) SPEED=SCALV
      RC=RC/SPEED
480   GO TO (490,530), KNTRL
C        IF RC IS ZERO, CONTINUE UNTIL RC IS POSITIVE.
490   IF (RC) 560,560,500
500   IF (I-1) 510,510,520
510   KNTRL=2
      GO TO 550
C        RESET POINT A TO LAST ONE PREVIOUS.
520   XA=XST(I-1)
      YA=YST(I-1)
      HA=HST(I-1)
      KNTRL=2
      GO TO 550
530   IF (RC) 540,540,550
C        RESET POINT B IF REACH ZERO CONCENTRATION.
540   XB=XI
      YB=YI
      HB=HI
      GO TO 580
550   KNT=KNT+1
560   XI=XI+DX
      YI=YI+DY
      HI=HI+DH
570   CONTINUE
580   IF (KNT) 600,600,590
590   IF (KNT-6) 410,410,640
C        IF GET TO 370, CONC. FROM THIS SEGMENT IS 0.
600   GO TO (610,620,630), INDIC
610   RC=0.
```

```
      GO TO 1060
620   FIRST=0.
      GO TO 1030
630   RC=FIRST
      GO TO 1050
640   CONTINUE
C        DO ANOTHER TRAPEZOIDAL INTEGRATION FROM A TO B IN TEN STEPS.
C        IT IS LIKELY THAT A TO B HAVE BEEN REDEFINED.
      DISX=XB-XA
      DISY=YB-YA
      DISH=0.001*(HB-HA)
      DISI=SQRT(DISX**2+DISY**2+DISH**2)
C        DISI IS DISTANCE(KM) FROM A TO B
      DELD=DISI*100.
C        DELD IS 1/10 DISI IN METERS.
      DX=DISX/10.
      DY=DISY/10.
      DH=(HB-HA)/10.
      SUM=0.
      XDUM=XA
      YDUM=YA
      IF (XDUM) 650,650,660
650   RC=0.
      GO TO 690
660   XZ=XDUM+XVZL
      XY=XDUM+XVYL
      H=HA
      GO TO (680,670), IUZS
670   UZ=U*(H/UHGT)**PWR
      IF (H.GT.200.) UZ=U*(200./UHGT)**PWR
      IF (UZ.LT.1.0) UZ=1.0
680   CALL RCONCP (Z,H,HL,XZ,XY,YDUM,KST,AN,M,SY,SZ,RC)
      RC=RC/UZ
690   CONTINUE
      HH=H*0.001
      DIS=DISTA(XDUM,YDUM,HH)/DISTOL
      SPEED=SQRT(VI+DELSPD*DIS)
      IF (SPEED.LT.SCALV) SPEED=SCALV
      RC=RC/SPEED
      SUM=SUM+RC/2.
      DO 750 I=1,9
      XDUM=XDUM+DX
      YDUM=YDUM+DY
      H=H+DH
      IF (XDUM) 700,700,710
700   RC=0.
      GO TO 740
710   GO TO (730,720), IUZS
720   UZ=U*(H/UHGT)**PWR
      IF (H.GT.200.) UZ=U*(200./UHGT)**PWR
      IF (UZ.LT.1.0) UZ=1.0
730   XZ=XDUM+XVZL
      XY=XDUM+XVYL
      CALL RCONCP (Z,H,HL,XZ,XY,YDUM,KST,AN,M,SY,SZ,RC)
      RC=RC/UZ
740   CONTINUE
      HH=H*0.001
      DIS=DISTA(XDUM,YDUM,HH)/DISTOL
      SPEED=SQRT(VI+DELSPD*DIS)
      IF (SPEED.LT.SCALV) SPEED=SCALV
      RC=RC/SPEED
750   SUM=SUM+RC
      XDUM=XDUM+DX
      YDUM=YDUM+DY
      H=H+DH
      IF (XDUM) 760,760,770
760   RC=0.
      GO TO 800
770   GO TO (790,780), IUZS
780   UZ=U*(H/UHGT)**PWR
      IF (H.GT.200.) UZ=U*(200./UHGT)**PWR
      IF (UZ.LT.1.0) UZ=1.0
790   XZ=XDUM+XVZL
      XY=XDUM+XVYL
      CALL RCONCP (Z,H,HL,XZ,XY,YDUM,KST,AN,M,SY,SZ,RC)
      RC=RC/UZ
800   CONTINUE
      HH=H*0.001
      DIS=DISTA(XDUM,YDUM,HH)/DISTOL
      SPEED=SQRT(VI+DELSPD*DIS)
      IF (SPEED.LT.SCALV) SPEED=SCALV
      RC=RC/SPEED
      SUM=SUM+RC/2.
C        INTEGRATED VALUE IS CURR.
      CURR=SUM*DELD
      ILIM=10
810   PREV=CURR
C        EVALUATE FOR POINTS IN BETWEEN THOSE ALREADY EVALUATED.
      DELD=DELD/2.
      XDUM=XA+DX/2.
      YDUM=YA+DY/2.
      H=HA+DH/2.
      GO TO (830,820), IUZS
820   UZ=U*(H/UHGT)**PWR
      IF (H.GT.200.) UZ=U*(200./UHGT)**PWR
      IF (UZ.LT.1.0) UZ=1.0
830   DO 890 I=1,ILIM
      IF (XDUM) 840,840,850
840   RC=0.
      GO TO 860
850   XZ=XDUM+XVZL
      XY=XDUM+XVYL
      CALL RCONCP (Z,H,HL,XZ,XY,YDUM,KST,AN,M,SY,SZ,RC)
      RC=RC/UZ
860   CONTINUE
      HH=H*0.001
      DIS=DISTA(XDUM,YDUM,HH)/DISTOL
      SPEED=SQRT(VI+DELSPD*DIS)
      IF (SPEED.LT.SCALV) SPEED=SCALV
      RC=RC/SPEED
C        NOTE ADD THESE TO RC'S FOUND ABOVE.
      SUM=SUM+RC
      H=H+DH
      GO TO (880,870), IUZS
870   UZ=U*(H/UHGT)**PWR
      IF (H.GT.200.) UZ=U*(200./UHGT)**PWR
      IF (UZ.LT.1.0) UZ=1.0
880   XDUM=XDUM+DX
890   YDUM=YDUM+DY
      CURR=SUM*DELD
      TEST=ABS((CURR-PREV)/CURR)
C        IF WITHIN PIN OF LAST VALUE (PREV), CONSIDER THIS AS FINAL VALU
      IF (TEST-PIN) 1000,900,900
900   ILIM=ILIM*2
      PREV=CURR
C        EVALUATE POINTS IN BETWEEN.
      DELD=DELD/2.
      DX=DX/2.
      DY=DY/2.
      DH=DH/2.
      XDUM=XA+DX/2.
      YDUM=YA+DY/2.
      H=HA+DH/2.
      GO TO (920,910), IUZS
910   UZ=U*(H/UHGT)**PWR
      IF (H.GT.200.) UZ=U*(200./UHGT)**PWR
      IF (UZ.LT.1.0) UZ=1.0
920   DO 980 I=1,ILIM
      IF (XDUM) 930,930,940
930   RC=0.
      GO TO 950
940   XZ=XDUM+XVZL
      XY=XDUM+XVYL
      CALL RCONCP (Z,H,HL,XZ,XY,YDUM,KST,AN,M,SY,SZ,RC)
      RC=RC/UZ
950   CONTINUE
      HH=H*0.001
      DIS=DISTA(XDUM,YDUM,HH)/DISTOL
      SPEED=SQRT(VI+DELSPD*DIS)
      IF (SPEED.LT.SCALV) SPEED=SCALV
      RC=RC/SPEED
      SUM=SUM+RC
      H=H+DH
      GO TO (970,960), IUZS
960   UZ=U*(H/UHGT)**PWR
      IF (H.GT.200.) UZ=U*(200./UHGT)**PWR
      IF (UZ.LT.1.0) UZ=1.0
970   XDUM=XDUM+DX
980   YDUM=YDUM+DY
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```
      CURR=SUM*DELD
      TEST=ABS((CURR-PREV)/CURR)
      IF (TEST-PIN) 1000,990,990
990   ILIM=ILIM*2
      DX=DX/2.
      DY=DY/2.
      DH=DH/2.
      GO TO 810
C        AT 1000 HAVE FINAL VALUE OF INTEGRATION IN CURR.
1000  GO TO (1010,1020,1040), INDIC
1010  RC=CURR
      GO TO 1050
1020  FIRST=CURR
1030  INDIC=3
      XA=XLOC
      YA=0.
      HA=HLOC
      XB=X2
      YB=Y2
      HB=H2
      GO TO 410
1040  RC=FIRST+CURR
1050  CONLS(NC,NW)=CONLS(NC,NW)+RC*QL*DVS(NW,
1060  CONTINUE
1070  CONTINUE
1080  CONTINUE
      RETURN
C
      END
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SPCCR

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      SUBROUTINE SPCCR (NHR,NQ,NR,PIN)
C        SPCCR CALCULATES HOURLY CONCENTRATIONS FROM A
C        SINGLE LANE CURVED PATH SOURCE. VEHICLES ARE
C        ALLOWED TO HAVE A CONSTANT ACCELERATION ALONG
C        THE PATH SOURCE.
C        THE FOLLOWING SUBROUTINES ARE CALLED BY SPCCR.
C          CURLIN--CALCULATES THE INTERSECTION OF THE
C                   LINE FORMED BY THE WIND DIRECTION AND
C                   RECEPTOR COORDINATES AND THE CIRCLE
C                   DETERMINED FROM POINTS A,B,C.
C          RCONCP--DETERMINES THE RELATIVE CONCENTRATION AT
C                  A RECEPTOR FROM A POINT AT A GIVEN UPWIND
C                  AND CROSSWIND DISTANCE.
C         THE FOLLOWING FUNCTIONS ARE CALLED BY SPCCR.
C           XVY--CALCULATES THE VIRTUAL DISTANCE NECESSARY
C                TO ACCOUNT FOR THE INITIAL CROSSWIND DISPERTION.
C           XVZ--CALCULATES THE VIRTUAL DISTANCE NECESSARY
C                TO ACCOUNT FOR THE INITIAL VERTICAL DISPERTION.
C           ANGARC--DETERMINES THE APPROPRIATE ARCTAN(M/N)
C                   WITH THE RESULTING ANGLE BETWEEN 0 AND
C                   360 DEGREES.
C           DIFANG--DETERMINES THE DIFFERENCE BETWEEN TWO ANGLES.
C                   THE RESULTING ANGLE IS BETWEEN 0 AND 360 DEGREES.
      COMMON /SOCS/ QLNA(31),HCL(31),RBQA(31),SBQA(31),RMQA(31),SMQA(31)
     1,REQA(31),SEQA(31),SIYA(31),SIZA(31),CONCLA(31,24),DVHA(31),IUZE,S
     2PEI(31),SPEF(31),TVCL(31),VSCL(31)
      COMMON /REC/ RR(31),SR(31),ZR(31)
      COMMON /WEA/ WTHET(25),WU(25),MKST(25),WHL(25),WTA(25),UHGT
      DIMENSION PUZ(6), RRR(11), SSS(11), DIR(11), ARC(5), XANG(5)
      DATA PUZ /0.15,0.15,0.20,0.25,0.40,0.60/
C     QLNA  PATH SOURCE STRENGTH FOR EACH LANE         (G/SEC)
C     HCL   HEIGHT OF THE PATH SOURCE                  (M)
C     RBQA  EAST COORDINATE,POINT A                    (KM)
C     SBQA  NORTH COORDINATE,POINT A                   (KM)
C     RMQA  EAST COORDINATE,POINT B                    (KM)
C     SMQA  NORTH COORDINATE,POINT B                   (KM)
C     REQA  EAST COORDINATE,POINT C                    (KM)
C     SEQA  NORTH COORDINATE,POINT C                   (KM)
C     SIYA  INITIAL SIGMA Y                            (M)
C     SIZA  INITIAL SIGMA Z                            (M)
C     CONCLA  CONCENTRATION                            (G/M**3)
C     DVHA  DIURNAL VARIATION,CURVED PATH SOURCE       (DIMENSIONLESS)
C     IUZE  WIND INCREASE WITH HEIGHT                  (DIMENSIONLESS)
C     SPEI  INITIAL VEHICLE SPEED                      (M/SEC)
C     SPEF  FINAL VEHICLE SPEED                        (M/SEC)
C     TVCL  VEHICLE VOLUME                             (VEH/HR)
C     VSCL  GROSS ESTIMATE OF VEHICLE SIZE             (M)
C     RR  EAST COORDINATE OF RECEPTOR                  (KM)
C     SR  NORTH COORDINATE OF RECEPTOR                 (KM)
C     ZR    HEIGHT OF RECEPTOR ABOVE GROUND            (M)
C     WTHET  WIND DIRECTION                            (DEG AZIMUTH)
C     WU  WIND SPEED                                   (M/SEC)
C     MKST  STABILITY CLASS                            (DIMENSIONLESS)
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C     WHL  MIXING HEIGHT                                 (M)
C     WTA  AMBIENT AIR SURFACE TEMP.                     (DEG K)
C     WP   AMBIENT AIR SURFACE PRESSURE                  (MB)
      X(R,S)=(R-RREC)*SINT+(S-SREC)*COST
C        X IS UPWIND DISTANCE OF R,S FROM RREC,SREC
      Y(R,S)=(S-SREC)*SINT-(R-RREC)*COST
C        Y IS CROSSWIND DISTANCE OF R,S FROM RREC,SREC
C     START DO LOOP FOR EACH HOUR
      DO 500 NW=1,NHR
      THETA=WTHET(NW)
      TR=THETA/57.2958
      SINT=SIN(TR)
      COST=COS(TR)
      U=WU(NW)
      UZ=U
      KST=MKST(NW)
      HL=WHL(NW)
      PWR=PUZ(KST)
C     START DO LOOP FOR EACH CURVED PATH
      DO 500 NS=1,NQ
      QL=QLNA(NS)*(TVCL(NS)/3600.)
      SCALV=VSCL(NS)*(TVCL(NS)/3600.)
      RB=RBQA(NS)
      RM=RMQA(NS)
      RE=REQA(NS)
      SB=SBQA(NS)
      SM=SMQA(NS)
      SE=SEQA(NS)
      VI=SPEI(NS)**2
      VF=SPEF(NS)**2
      DELSPD=VF-VI
      H=HCL(NS)
      GO TO (20,10), IUZE
10    UZ=U*(H/UHGT)**PWR
      IF (H.GT.200.) UZ=U*(200./UHGT)**PWR
      IF (UZ.LT.1.0) UZ=1.0
20    IF (SIYA(NS)) 40,30,40
30    XVYL=0.
      GO TO 50
40    SYON=SIYA(NS)
      XVYL=XVY(SYON,KST)
50    IF (SIZA(NS)) 70,60,70
60    XVZL=0.
      GO TO 80
70    SZON=SIZA(NS)
      XVZL=XVZ(SZON,KST)
80    CONTINUE
C     FROM HERE THROUGH STATEMENT 150 THE CENTER AND RADIUS OF THE
C     CIRCLE,THROUGH POINTS A,B AND C,ARE CALCULATED
      RMID=(RB+RM)/2.
      SMID=(SB+SM)/2.
      RNID=(RM+RE)/2.
      SNID=(SM+SE)/2.
      IF (RM-RB.EQ.0.) GO TO 90
      IF (RE-RM.EQ.0.) GO TO 100
      SLO1=-((RM-RB)/(SM-SB))
      SLO2=-((RE-RM)/(SE-SM))
      RC=(SLO1*RMID+SNID-SMID-SLO2*RNID)/(SLO1-SLO2)
      SC=SLO1*(RC-RMID)+SMID
      GO TO 110
90    RC=RMID
      SLO2=-((RE-RM)/(SE-SM))
      SC=SLO2*(RC-RNID)+SNID
      GO TO 110
100   RC=RNID
      SLO1=-((RM-RB)/(SM-SB))
      SC=SLO1*(RC-RMID)+SMID
      GO TO 110
110   RAD=SQRT((RC-RB)**2+(SC-SB)**2)
      DELM=RB-RC
      DELN=SB-SC
      ANGB=ANGARC(DELM,DELN)
      DELM=RM-RC
      DELN=SM-SC
      ANGM=ANGARC(DELM,DELN)
      DELM=RE-RC
      DELN=SE-SC
      ANGE=ANGARC(DELM,DELN)
      ANGBE=ABS(DIFANG(ANGB,ANGE))
      ANGBM=ABS(DIFANG(ANGB,ANGM))
      ANGME=ABS(DIFANG(ANGM,ANGE))
      IF (ANGBM.LT.ANGBE.AND.ANGME.LT.ANGBE) GO TO 120
      GAMDEG=360.-ANGBE
      GO TO 130
120   GAMDEG=ANGBM+ANGME
130   CONTINUE
C     GAMDEG IS THE ANGLE SUBTENDED BY THE ARC ABC
C     IF A=1 THE ROTATION FROM A TO B IS CLOCKWISE
C     IF A=-1 THE ROTATION FROM A TO B IS COUNTER-CLOCKWISE
      A=1.
      IF (GAMDEG.GE.180.) GO TO 140
      BEDEG=DIFANG(ANGE,ANGB)
      IF (BEDEG.LT.0.) A=-1.
      GO TO 150
140   RDEG=ANGB+180.
      RMDEG=DIFANG(ANGM,RDEG)
      REDEG=DIFANG(ANGE,RDEG)
      IF (RMDEG.GE.0..AND.REDEG.LE.0.) A=-1.
150   CONTINUE
      DO 500 NC=1,NR
      RREC=RR(NC)
      SREC=SR(NC)
      Z=ZR(NC)
C     CURLIN CALCULATES THE COORDINATES OF ANY UPWIND LOCI ON ARC AB
C     FROM HERE TO STATEMENT 310 THE BEGINNING AND ENDING
C     POINTS,WITH THEIR CORRESPONDING DIRECTIONS,FOR EACH SEGMENT
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C     OF THE ARC ARE CALCULATED
      CALL CURLIN (RC,SC,RREC,SREC,Z,RAD,THETA,RL,SL,RL1,SL1,NLOCI)
      IF (NLOCI) 160,170,180
C     NLOCI HAS VALUES OF -1,0,OR 1 FOR:
C     NO UPWIND LOCI ON ARC AB: 1 LOCI ON ARC AB:
C     OR 2 LOCI ON ARC AB
160   XANG(1)=ANGB
      ARC(1)=GAMDEG
      J=1
      GO TO 310
170   K=1
      GO TO 190
180   K=2
190   N=1
      DO 270 KK=1,K
      IF (KK.EQ.2) GO TO 200
      DELM=RL-RC
      DELN=SL-SC
      ANGRL=ANGARC(DELM,DELN)
      RANG=ANGRL
      GO TO 220
200   DELM=RL1-RC
210   IF (K.NE.1) GO TO 270
      XANG(1)=ANGB
      ARC(1)=GAMDEG
      DELN=SL1-SC
      ANGRL=ANGARC(DELM,DELN)
      RLANG=ANGRL
220   IF (GAMDEG.GT.180..AND.A.GT.0.) GO TO 230
      IF (GAMDEG.GE.180..AND.A.LT.0.) GO TO 240
      IF (GAMDEG.LT.180..AND.A.LT.0.) GO TO 250
      BIN=DIFANG(ANGRL,ANGB)
      IF (BIN.LE.0..OR.BIN.GE.GAMDEG) GO TO 210
      ARC(N)=BIN
      GO TO 260
230   BIN=DIFANG(ANGRL,ANGB)
      IF (BIN.GT.0.) ARC(N)=BIN
      IF (BIN.GT.0.) GO TO 260
      IF (BIN.LE.0.) DIF=(GAMDEG-360.)-BIN
      IF (DIF.LT.0.) GO TO 210
      ARC(N)=BIN+360.
      GO TO 260
240   BIN=DIFANG(ANGRL,ANGB)
      IF (BIN.LT.0.) ARC(N)=BIN
      IF (BIN.LT.0.) GO TO 260
      IF (BIN.GE.0..AND.BIN.LE.360.-GAMDEG) GO TO 210
      ARC(N)=360.-BIN
      GO TO 260
250   BIN=DIFANG(ANGRL,ANGB)
      IF (BIN.GE.0..OR.BIN.LE.-GAMDEG) GO TO 210
      ARC(N)=BIN
      GO TO 260
260   N=N+1
```

```
      INDEX=-1
      IF (KK.EQ.2) INDEX=1
      GO TO 270
270   CONTINUE
      XANG(1)=ANGB
      IF (N-1.EQ.0) GO TO 300
      IF (N-1.EQ.2) GO TO 280
      ARC(2)=GAMDEG-ABS(ARC(1))
      XANG(2)=RANG
      IF (INDEX.EQ.1) XANG(2)=RLANG
      J=2
      GO TO 310
280   ARC(1)=ABS(ARC(1))
      ARC(2)=ABS(ARC(2))
      IF (ARC(1).GT.ARC(2)) GO TO 290
      ARC(2)=ARC(2)-ARC(1)
      ARC(3)=GAMDEG-ARC(1)-ARC(2)
      XANG(2)=RANG
      XANG(3)=RLANG
      J=3
      GO TO 310
290   AA=ARC(1)
      ARC(1)=ARC(2)
      ARC(2)=AA-ARC(2)
      ARC(3)=GAMDEG-ARC(1)-ARC(2)
      XANG(2)=RLANG
      XANG(3)=RANG
      J=3
      GO TO 310
300   J=1
      ARC(1)=GAMDEG
310   TOTAL=0.
      DISTOT=RAD*(GAMDEG/57.29578)
      DO 490 M=1,J
      KNT=0
      NCHI=0
      NM=0
      LCOUNT=0
C     CHI VALUES ARE CALCULATED FOR 11 POINTS ON THE ARC SEGMENT.
C     THE SEGMENT IS REDUCED IN SIZE UNTIL AT LEAST 7 OF THE 11 CHI
C     VALUES ARE NON-ZERO.
320   DO 370 L=1,11
      DIR(L)=XANG(M)+(A*(L-1)/10.)*ABS(ARC(M))
      IF (DIR(L).GT.360.) DIR(L)=DIR(L)-360.
      IF (DIR(L).LT.0.) DIR(L)=DIR(L)+360.
      DIRRAD=DIR(L)/57.29578
      RRR(L)=RC+RAD*SIN(DIRRAD)
      SSS(L)=SC+RAD*COS(DIRRAD)
      XZ=X(RRR(L),SSS(L))+XVZL
      XY=X(RRR(L),SSS(L))+XVYL
      YI=Y(RRR(L),SSS(L))
      IF (XZ-XVZL) 330,330,340
330   CHI=0.
```

```
      GO TO 350
340   CALL RCONCP (Z,H,HL,XZ,XY,YI,KST,AN,MI,SY,SZ,CHI)
350   IF (CHI) 370,370,360
360   NM=NM+1
      NCHI=NCHI+1
C     THE NEXT TWO STEPS DETERMINE THE DIRECTION FROM
C     THE CENTER TO THE NEW STARTING POINT
      IF (L.EQ.1) DIRINT=DIR(L)
      IF (NM.EQ.1.AND.L.GT.1) DIRINT=DIR(L-1)
      IF (L.GT.1.AND.NM.EQ.1) NM=2
      LCOUNT=0
      IF (L.NE.11) LCOUNT=1
370   CONTINUE
      NM=NM+LCOUNT
C     NM-1 IS THE NUMBER OF NON-ZERO SECTIONS OF THE ARC SEGMENT
      IF (NM) 470,470,380
380   IF (NCHI.GT.6) GO TO 390
      VAR=NM-1
      ARC(M)=ABS(ARC(M))*(VAR/10.)
      XANG(M)=DIRINT
      NM=0
      NCHI=0
      GO TO 320
C     DO A TRAPEZOIDAL INTEGRATION FROM A TO B IN TEN STEPS.
C     IT IS LIKELY THAT A OR B HAVE BEEN REDEFINED.
390   II=11
      L=1
      KK=1
      SUM=0.
      VAR=NM-1
      ARR=ABS(ARC(M))*(VAR/10.)
      DELL=((ARR/10.)/57.29578)*RAD*1000.
C     DELL=1/10 OF THE ARC LENGTH IN METERS
400   DO 440 I=L,II,KK
      DIV=II-1.
      DIRR=DIRINT+(A*(I-1)/DIV)*ARR
      DIRRAD=DIRR/57.29578
      RRR1=RC+RAD*SIN(DIRRAD)
      SSS1=SC+RAD*COS(DIRRAD)
      XZ=X(RRR1,SSS1)+XVZL
      XY=X(RRR1,SSS1)+XVYL
      YI=Y(RRR1,SSS1)
      DTHETA=DIFANG(DIRR,ANGB)
      IF (A.LT.0..AND.DTHETA.GT.0.) DTHETA=360.-ABS(DTHETA)
      IF (A.GT.0..AND.DTHETA.LT.0.) DTHETA=360.-ABS(DTHETA)
      DIS=(RAD*(DTHETA/57.29578))/DISTOT
      SPEED=SQRT(VI+DELSPD*DIS)
      IF (SPEED.LT.SCALV) SPEED=SCALV
      IF (XZ-XVZL) 410,410,420
410   CHI=0.
      GO TO 430
420   CALL RCONCP (Z,H,HL,XZ,XY,YI,KST,AN,MI,SY,SZ,CHI)
430   CHI=CHI/SPEED
```

```
      IF (I.EQ.1) Q1=CHI/2.
      IF (I.EQ.II) Q2=CHI/2.
      SUM=SUM+CHI
440   CONTINUE
      KNT=KNT+1
      IF (KNT.GT.1) GO TO 450
      TOTQ=SUM-Q1-Q2
      TOTQ2=TOTQ*DELL
      SUM=0.
      DELL=DELL/2.
      II=21
      L=2
      KK=2
      GO TO 400
450   CONTINUE
C     SECOND ESTIMATE COMPLETED HERE.
      TOTQ=TOTQ+SUM
      TOTQ1=TOTQ*DELL
      TEST=ABS((TOTQ1-TOTQ2)/TOTQ1)
C     COMPARE LAST ESTIMATE WITH PREVIOUS ESTIMATE,IF WITHIN
C     PIN OF EACH OTHER CONSIDER THIS AS FINAL VALUE.
      IF (TEST-PIN) 480,460,460
C     SET LAST ESTIMATE=PREVIOUS ESTIMATE AND CONTINUE TO
C     EVALUATE FOR POINTS IN BETWEEN.
460   TOTQ2=TOTQ1
      DELL=DELL/2.
      II=2*II-1
      SUM=0.
      GO TO 400
470   TOTQ1=0.
480   CONTINUE
      TOTAL=TOTAL+TOTQ1
490   CONTINUE
      CONCLA(NC,NW)=CONCLA(NC,NW)+TOTAL*QL*DWHA(NW)/34
500   CONTINUE
      RETURN
C
      END
```

XPLUME

```
      SUBROUTINE XPLUME (HX,F,DELHF,HP,U,X)
C        BRIGGS EFFECTIVE HEIGHT AT THE DISTANCE X.
C          OUTPUT VARIABLES ARE...
C            HX    EFFECTIVE PLUME HEIGHT FOR DISTANCE X (METERS)
C          INPUT VARIABLES ARE...
C            F     BUOYANCY FLUX (M**4/SEC**3)
C            DELHF FINAL PLUME RISE (METERS)
C            HP    PHYSICAL STACK HEIGHT (METERS)
C            U     WIND SPEED (M/SEC)
C            X     DOWNWIND DISTANCE (KM)
      XM=1000.*X
C        XM IS X IN METERS.
C        STATEMENT 10 IS EQUATION (2), BRIGGS(1971).
10    DELHX=1.6*F**0.333333*XM**0.666667/U
      IF (DELHX.GT.DELHF) DELHX=DELHF
      HX=HP+DELHX
      RETURN
C
      END
```

FPLUME

```
      SUBROUTINE FPLUME (HF,DISTF,F,DELHF,HP,TS,VS,D,VF,KST,U,DTHDZ,T)
C        BRIGGS FINAL HEIGHT
C        D. B. TURNER, ENVIRONMENTAL APPLICATIONS BRANCH
C         METEOROLOGY LABORATORY, ENVIRONMENTAL PROTECTION AGENCY
C          RESEARCH TRIANGLE PARK, N C 27711
C             (919) 549 - 8411, EXTENSION 4565
      IF (T) 10,10,20
C        T = 0. MEANS NO AMBIENT TEMPERATURE GIVEN.  USE T = 293.
10    T=293.
C         OUTPUT VARIABLES ARE...
C           HF    FINAL EFFECTIVE PLUME HEIGHT (METERS)
C           F     BUOYANCY FLUX (M**4/SEC**3)
C           DELHF FINAL PLUME RISE (METERS)
C           DISTF DISTANCE OF FINAL PLUME RISE FROM SOURCE (KM)
C         INPUT VARIABLES ARE...
C           HP    PHYSICAL STACK HEIGHT (METERS)
C           TS    STACK GAS TEMPERATURE (DEG K)
C           VS    STACK GAS EXIT VELOCITY (M/SEC)
C           D     INSIDE STACK DIAMETER (METERS)
C           VF    STACK GAS VOLUMETRIC FLOW RATE (M**3/SEC)
C           KST   STABILITY (CLASS), SEE PAGE 209 OF PASQUILL,
C                  ATMOSPHERIC DISPERSION.  CLASSES DEFINED BY...
C                    1 IS PASQUILL STABILITY CLASS A
C                    2 IS PASQUILL STABILITY CLASS B
C                    3 IS PASQUILL STABILITY CLASS C
C                    4 IS PASQUILL STABILITY CLASS D
C                    5 IS PASQUILL STABILITY CLASS E
C                    6 IS PASQUILL STABILITY CLASS F
C           U     WIND SPEED (M/SEC)
C           DTHDZ POTENTIAL TEMPERATURE LAPSE RATE (DEG K/METER)
C           T     AMBIENT AIR TEMPERATURE (DEG K)
C        IF VF IS NOT GIVEN, CALCULATE IT FROM STACK DATA.
20    IF (VF) 30,30,40
30    VF=0.785398*VS*D*D
C        THE CONSTANT 0.785398 = PI/4
40    F=3.12139*VF*(TS-T)/TS
C        THE CONSTANT 3.12139 IS THE ACCELERATION DUE TO GRAVITY / PI.
C        GO TO APPROPRIATE BRANCH FOR STABILITY CONDITION GIVEN.
C        IF UNSTABLE OR NEUTRAL GO TO 50, IF STABLE GO TO 90.
      GO TO (50,50,50,50,90,90,90), KST
C        DETERMINE APPROPRIATE FORMULA FOR CALCULATING XST, DISTANCE AT
C         WHICH TURBULENCE BEGINS TO DOMINATE.  THE FORMULA USED DEPENDS
C         UPON BUOYANCY FLUX. STATEMENTS 60 AND 70 ARE EQUATION (7),
C         BRIGGS(1971).
50    IF (F-55.) 60,70,70
60    XST=14.*F**.625
      GO TO 80
70    XST=34.*F**.4
80    DISTF=3.5*XST
      DELHF=1.6*F**0.333333*DISTF**0.666667/U
      GO TO 160
90    IF (DTHDZ) 100,100,130
C        IF DTHDZ IS NEGATIVE OR ZERO ASSIGN TO IT A VALUE OF 0.02 OR
```

```
C         0.035 IF STABILITY IS SLIGHTLY STABLE OR STABLE, RESPECTIVELY.
100   GO TO (50,50,50,50,110,120,120), KST
110   DTHDZ=0.02
      GO TO 130
120   DTHDZ=0.035
130   S=9.80616*DTHDZ/T
C        THE CONSTANT 9.80616 IS THE ACCELERATION DUE TO GRAVITY.
C        S IS A STABILITY PARAMETER.
C        CALCULATE PLUME RISE ACCORDING TO EQUATION (2), BRIGGS(1972).
      DHA=2.4*(F/(U*S))**0.333333
C        CALCULATE PLUME RISE BY EQUATION (5), BRIGGS(1971) FOR LIGHT
C         WIND CONDITIONS ACCORDING TO MORTON, TAYLOR, AND TURNER.
      DELHF=5.0*F**0.25/S**0.375
      IF (DHA-DELHF) 140,140,150
140   DELHF=DHA
C        DISTANCE TO FINAL PLUME RISE IS GIVEN BY THE FOLLOWING
150   DISTF=3.14159*U/S**0.5
C        CALCULATE FINAL EFFECTIVE HEIGHT.
160   HF=HP+DELHF
      DISTF=DISTF/1000.
      RETURN
C
      END
```

PGSIG

```
      SUBROUTINE PGSIG (X,XY,KST,SY,SZ)
C         D. B. TURNER, ENVIRONMENTAL APPLICATIONS BRANCH
C           METEOROLOGY LABORATORY, ENVIRONMENTAL PROTECTION AGENCY
C             RESEARCH TRIANGLE PARK, N C 27711
C                (919) 549 - 8411, EXTENSION 4565
C         VERTICAL DISPERSION PARAMETER VALUE, SZ DETERMINED BY
C           SZ = A * X ** B WHERE A AND B ARE FUNCTIONS OF BOTH STABILITY
C           AND RANGE OF X.
C         HORIZONTAL DISPERSION PARAMETER VALUE, SY DETERMINED BY
C           LOGARITHMIC INTERPOLATION OF PLUME HALF-ANGLE ACCORDING TO
C           DISTANCE AND CALCULATION OF 1/2.15 TIMES HALF-ARC LENGTH.
      DIMENSION XA(7), XB(2), XD(5), XE(8), XF(9), AA(8), BA(8), AB(3),
     1BB(3), AD(6), BD(6), AE(9), BE(9), AF(10), BF(10)
      DATA XA /.5,.4,.3,.25,.2,.15,.1/
      DATA XB /.4,.2/
      DATA XD /30.,10.,3.,1.,.3/
      DATA XE /40.,20.,10.,4.,2.,1.,.3,.1/
      DATA XF /60.,30.,15.,7.,3.,2.,1.,.7,.2/
      DATA AA /453.85,346.75,258.89,217.41,179.52,170.22,158.08,122.8/
      DATA BA /2.1166,1.7283,1.4094,1.2644,1.1262,1.0932,1.0542,.9447/
      DATA AB /109.3j51d7md"51j7gx"/
      DATA BB /1.0971,0.98332,0.93198/
      DATA AD /44.053,36.650,33.504,32.093,32.093,34.459/
      DATA BD /0.51179,0.56589,0.60486,0.64403,0.81066,0.86974/
      DATA AE /47.618,35.420,26.970,24.703,22.534,21.628,21.628,23.331,2
     14.26/
      DATA BE /0.29592,0.37615,0.46713,0.50527,0.57154,0.63077,0.75660,0
     1.81956,0.8366/
      DATA AF /34.219,27.074,22.651,17.836,16.187,14.823,13.953,13.953,1
     14.457,15.209/
      DATA BF /0.21716,0.27436,0.32681,0.41507,0.46490,0.54503,0.63227,0
     1.68465,0.78407,0.81558/
      GO TO (10,40,70,80,110,140), KST
C         STABILITY A (10)
10    TH=(24.167-2.5334*ALOG(XY))/57.2958
      IF (X.GT.3.11) GO TO 170
      DO 20 ID=1,7
      IF (X.GE.XA(ID)) GO TO 30
20    CONTINUE
      ID=8
30    SZ=AA(ID)*X**BA(ID)
      GO TO 190
C         STABILITY B (40)
40    TH=(18.333-1.8096*ALOG(XY))/57.2958
      IF (X.GT.35.) GO TO 170
      DO 50 ID=1,2
      IF (X.GE.XB(ID)) GO TO 60
50    CONTINUE
      ID=3
60    SZ=AB(ID)*X**BB(ID)
      GO TO 180
C         STABILITY C (70)
70    TH=(12.5-1.0857*ALOG(XY))/57.2958
```

```
      SZ=61.141*X**0.91465
      GO TO 180
C        STABILITY D (80)
 80   TH=(8.3333-0.72382*ALOG(XY))/57.2958
      DO 90 ID=1,5
      IF (X.GE.XD(ID)) GO TO 100
 90   CONTINUE
      ID=6
 100  SZ=AD(ID)*X**BD(ID)
      GO TO 180
C        STABILITY E (110)
 110  TH=(6.25-0.54287*ALOG(XY))/57.2958
      DO 120 ID=1,8
      IF (X.GE.XE(ID)) GO TO 130
 120  CONTINUE
      ID=9
 130  SZ=AE(ID)*X**BE(ID)
      GO TO 180
C        STABILITY F (140)
 140  TH=(4.1667-0.36191*ALOG(XY))/57.2958
      DO 150 ID=1,9
      IF (X.GE.XF(ID)) GO TO 160
 150  CONTINUE
      ID=10
 160  SZ=AF(ID)*X**BF(ID)
      GO TO 180
 170  SZ=5000.
      GO TO 190
 180  IF (SZ.GT.5000.) SZ=5000.
 190  SY=465.116*XY*SIN(TH)/COS(TH)
C        465.116 = 1000. (M/KM) / 2.15
      RETURN
C
      END
```

RCONCP

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```
      SUBROUTINE RCONCP (Z,H,HL,X,XY,Y,KST,AN,M,SY,SZ,RC)
C        D. B. TURNER, RESEARCH METEOROLOGIST* MODEL DEVELOPMENT BRANCH,
C         DIVISION OF METEOROLOGY, ENVIRONMENTAL PROTECTION AGENCY.
C           ROOM 314B, NCHS BUILDING, RTP. PHONE (919) 549-8411 EXT 4564
C          MAILING ADDRESS- DM, EPA, RESEARCH TRIANGLE PARK, NC 27711
C         * ON ASSIGNMENT FROM NATIONAL OCEANIC AND ATMOSPHERIC
C               ADMINISTRATION, DEPARTMENT OF COMMERCE.
C        SUBROUTINE RCONCP CALCULATES CHI*U/Q CONCENTRATION VALUES
C         RCONCP CALLS SUBROUTINE PGSIG TO OBTAIN STANDARD DEVIATIONS.
C        THE INPUT VARIABLES ARE....
C         Z    RECEPTOR HEIGHT (M)
C         H    EFFECTIVE STACK HEIGHT (M)
C         HL=L HEIGHT OF LIMITING LID (M)
C         X    DISTANCE RECEPTOR IS DOWNWIND OF SOURCE (KM)
C         XY   X+VIRTUAL DISTANCE USED FOR AREA SOURCE APPROX. (KM)
C         Y    DISTANCE RECEPTOR IS CROSSWIND FROM SOURCE (KM)
C         KST  STABILITY CLASS
C        THE OUTPUT VARIABLES ARE....
C         AN   THE NUMBER OF TIMES THE SUMMATION TERM IS EVALUATED
C               AND ADDED IN.
C         RC   RELATIVE CONCENTRATION (SEC/M**3)
C        THE FOLLOWING EQUATION IS SOLVED --
C          RC = (1/(2*PI*SIGMA Y*SIGMA Z))* (EXP(-0.5*(Y/SIGMA Y)**2))
C           (EXP(-0.5*((Z-H)/SIGMA Z)**2) + EXP(-0.5*((Z+H)/SIGMA Z)**2)
C             PLUS THE SUM OF THE FOLLOWING 4 TERMS K TIMES (N=1,K) --
C              TERM 1- EXP(-0.5*((Z-H-2NL)/SIGMA Z)**2)
C              TERM 2- EXP(-0.5*((Z+H-2NL)/SIGMA Z)**2)
C              TERM 3- EXP(-0.5*((Z-H+2NL)/SIGMA Z)**2)
C              TERM 4- EXP(-0.5*((Z+H+2NL)/SIGMA Z)**2)
C        THE ABOVE EQUATION IS SIMILAR TO EQUATION (5.8) P 36 IN
C         WORKBOOK OF ATMOSPHERIC DISPERSION ESTIMATES WITH THE ADDITION
C         OF THE EXPONENTIAL INVOLVING Y,TURNER(1970).
C        IWRI IS CONTROL CODE FOR OUTPUT
      IWRI=6
C        IF THE SOURCE IS ABOVE THE LID, SET RC = 0., AND RETURN.
      IF(KST.GE.5) GO TO 50
      IF (H-HL) 10,10,20
10    IF (Z-HL) 50,50,40
20    IF (Z-HL) 40,30,30
30    WRITE (IWRI,460)
40    RC=0.
      RETURN
C        IF X IS LESS THAN 1 METER, SET RC=0. AND RETURN.  THIS AVOIDS
C         PROBLEMS OF INCORRECT VALUES NEAR THE SOURCE.
50    IF (X-0.001) 40,60,60
C        CALL PGSIG TO OBTAIN VALUES FOR SY AND SZ
60    CALL PGSIG (X,XY,KST,SY,SZ)
C         SY = SIGMA Y, THE STANDARD DEVIATION OF CONCENTRATION IN THE
C         Y-DIRECTION (M)
C         SZ = SIGMA Z, THE STANDARD DEVIATION OF CONCENTRATION IN THE
C         Z-DIRECTION (M)
      C1=1.
      IF (Y) 70,90,70
```

```
70      YD=1000.*Y
C          YD IS CROSSWIND DISTANCE IN METERS.
        DUM=YD/SY
        TEMP=0.5*DUM*DUM
        IF (TEMP-50.) 80,40,40
80      C1=EXP(TEMP)
90      IF (KST-4) 100,100,110
100     IF (HL-5000.) 190,110,110
C          IF STABLE CONDITION OR UNLIMITED MIXING HEIGHT,
C           USE EQUATION 3.2 IF Z = 0, OR EQ 3.1 FOR NON-ZERO Z,
C            TURNER(1970).
110     C2=2.*SZ*SZ
        IF (Z) 40,120,140
120     C3=H*H/C2
        IF (C3-50.) 130,40,40
130     A2=1./EXP(C3)
C          WADE EQUATION 3.2,TURNER(1970).
        RC=A2/(3.14159*SY*SZ*C1)
        M=1
        RETURN
140     A2=0.
        A3=0.
        CA=Z-H
        CB=Z+H
        C3=CA*CA/C2
        C4=CB*CB/C2
        IF (C3-50.) 150,160,160
150     A2=1./EXP(C3)
160     IF (C4-50.) 170,180,180
170     A3=1./EXP(C4)
C          WADE EQUATION 3.1,TURNER(1970).
180     RC=(A2+A3)/(6.28318*SY*SZ*C1)
        M=2
        RETURN
C          IF SIGMA-Z IS GREATER THAN 1.6 TIMES THE MIXING HEIGHT,
C           THE DISTRIBUTION BELOW THE MIXING HEIGHT IS UNIFORM WITH
C           HEIGHT REGARDLESS OF SOURCE HEIGHT.
190     IF (SZ/HL-1.6) 210,210,200
C          WADE EQUATION 3.5,TURNER(1970).
200     RC=1./(2.5066*SY*HL*C1)
        M=3
        RETURN
C          INITIAL VALUE OF AN SET = 0.
210     AN=0.
        IF (Z) 40,370,220
C          STATEMENTS 220 TO 360 CALCULATE RC, THE RELATIVE CONCENTRATION,
C           USING THE EQUATION DISCUSSED ABOVE.  SEVERAL INTERMEDIATE
C           VARIABLES ARE USED TO AVOID REPEATING CALCULATIONS.
C           CHECKS ARE MADE TO BE SURE THAT THE ARGUMENT OF THE
C           EXPONENTIAL FUNCTION IS NEVER GREATER THAN 50 (OR LESS THAN
C           -50).  IF 'AN' BECOMES GREATER THAN 45, A LINE OF OUTPUT IS
C           PRINTED INFORMING OF THIS.
C          CALCULATE MULTIPLE EDDY REFLECTIONS FOR RECEPTOR HEIGHT Z.
```

```
220   A1=1./(6.28318*SY*SZ*C1)
      C2=2.*SZ*SZ
      A2=0.
      A3=0.
      CA=Z-H
      CB=Z+H
      C3=CA*CA/C2
      C4=CB*CB/C2
      IF (C3-50.) 230,240,240
230   A2=1./EXP(C3)
240   IF (C4-50.) 250,260,260
250   A3=1./EXP(C4)
260   SUM=0.
      THL=2.*HL
270   AN=AN+1.
      A4=0.
      A5=0.
      A6=0.
      A7=0.
      C5=AN*THL
      CC=CA-C5
      CD=CB-C5
      CE=CA+C5
      CF=CB+C5
      C6=CC*CC/C2
      C7=CD*CD/C2
      C8=CE*CE/C2
      C9=CF*CF/C2
      IF (C6-50.) 280,290,290
280   A4=1./EXP(C6)
290   IF (C7-50.) 300,310,310
300   A5=1./EXP(C7)
310   IF (C8-50.) 320,330,330
320   A6=1./EXP(C8)
330   IF (C9-50.) 340,350,350
340   A7=1./EXP(C9)
350   T=A4+A5+A6+A7
      SUM=SUM+T
      IF (T-0.01) 360,270,270
360   RC=A1*(A2+A3+SUM)
      M=5
      RETURN
C        CALCULATE MULTIPLE EDDY REFLECTIONS FOR GROUND LEVEL RECEPTOR H
370   A1=1./(6.28318*SY*SZ*C1)
      A2=0.
      C2=2.*SZ*SZ
      C3=H*H/C2
      IF (C3-50.) 380,390,390
380   A2=2./EXP(C3)
390   SUM=0.
      THL=2.*HL
400   AN=AN+1.
      A4=0.
```

RCONCP

```
      A6=0.
      C5=AN*THL
      CC=H-C5
      CE=H+C5
      C6=CC*CC/C2
      C8=CE*CE/C2
      IF (C6-50.) 410,420,420
  410 A4=2./EXP(C6)
  420 IF (C8-50.) 430,440,440
  430 A6=2./EXP(C8)
  440 T=A4+A6
      SUM=SUM+T
      IF (T-0.01) 450,400,400
  450 RC=A1*(A2+SUM)
      M=4
      RETURN
C
  460 FORMAT (1H0,'BOTH H AND Z ARE ABOVE THE MIXING HEIGHT SO A RELIABL
     1E COMPUTATION CAN NOT BE MADE.')
C
      END
```

RCONCA

```
      SUBROUTINE RCONCA (Z,H,HL,X,KST,AN,M,SZ,RCZ)
C        SUBROUTINE RCONCA CALCULATES CHI*U/Q, RELATIVE CONCENTRATION
C         NORMALIZED FOR WIND SPEED FOR A RECEPTOR DOWNWIND OF A
C         CROSSWIND INFINATE LINE SOURCE.
C        D. B. TURNER, RESEARCH METEOROLOGIST* MODEL APPLICATIONS BRANCH
C         METEOROLOGY LABORATORY, ENVIRONMENTAL PROTECTION AGENCY.
C           ROOM 316B, NCHS BUILDING, RTP. PHONE (919) 549-8411 EXT 4564
C        MAILING ADDRESS: MTL,EPA, RESEARCH TRIANGLE PARK, NC 27711.
C         * ON ASSIGNMENT FROM NATIONAL OCEANIC AND ATMOSPHERIC
C               ADMINISTRATION, DEPARTMENT OF COMMERCE.
C        THE INPUT VARIABLES ARE....
C         Z    RECEPTOR HEIGHT (M)
C         H    EFFECTIVE STACK HEIGHT (M)
C         HL=  HEIGHT OF LIMITING LID (M)
C         X    DISTANCE RECEPTOR IS DOWNWIND OF SOURCE (KM)
C         KST  STABILITY CLASS
C         SZ = SIGMA Z, THE STANDARD DEVIATION OF CONCENTRATION IN THE
C         Z-DIRECTION (M)
C        THE OUTPUT VARIABLES ARE....
C         AN   THE NUMBER OF TIMES THE SUMMATION TERM IS EVALUATED
C               AND ADDED IN.
C        RCZ   RELATIVE CONCENTRATION (DIMENSIONLESS)
C        IWRI IS CONTROL CODE FOR OUTPUT
      IWRI=6
C        THE FOLLOWING EQUATION IS SOLVED --
C        RC = (1/2.5066 *SIGMA Z))* (EXP(-0.5*(Y/SIGMA Y)**2)) *
C           (EXP(-0.5*((Z-H)/SIGMA Z)**2) + EXP(-0.5*((Z+H)/SIGMA Z)**2)
C             PLUS THE SUM OF THE FOLLOWING 4 TERMS K TIMES (N=1,K) --
C              TERM 1- EXP(-0.5*((Z-H-2NL)/SIGMA Z)**2)
C              TERM 2- EXP(-0.5*((Z+H-2NL)/SIGMA Z)**2)
C              TERM 3- EXP(-0.5*((Z-H+2NL)/SIGMA Z)**2)
C              TERM 4- EXP(-0.5*((Z+H+2NL)/SIGMA Z)**2)
C        2.5066 IS THE SQUARE ROOT OF 2 * PI
C        STATEMENTS 190 TO 330 CALCULATE RC, THE RELATIVE CONCENTRATION,
C         USING THE EQUATION DISCUSSED ABOVE.  SEVERAL INTERMEDIATE
C         VARIABLES ARE USED TO AVOID REPEATING CALCULATIONS.
C         CHECKS ARE MADE TO BE SURE THAT THE ARGUMENT OF THE
C         EXPONENTIAL FUNCTION IS NEVER GREATER THAN 50 (OR LESS THAN
C         -50).  IF 'AN' BECOMES GREATER THAN 45, A LINE OF OUTPUT IS
C         PRINTED INFORMING OF THIS.
C        CALCULATE MULTIPLE EDDY REFLECTIONS FOR RECEPTOR HEIGHT Z.
C        IF THE SOURCE IS ABOVE THE LID, SET RC = 0., AND RETURN.
      IF(KST.GE.5) GO TO 40
      IF (H-HL) 10,10,20
10    IF (Z-HL) 40,40,180
20    IF (Z-HL) 180,30,30
30    WRITE (IWRI,430)
      RETURN
C        IF X IS LESS THAN 1 METER, SET RC=0. AND RETURN.  THIS AVOIDS
C         PROBLEMS OF INCORRECT VALUES NEAR THE SOURCE.
40    IF (X-0.001) 180,50,50
50    IF (KST-4) 60,60,70
60    IF (HL-5000.) 150,70,70
```

```
C          IF STABLE CONDITION OR UNLIMITED MIXING HEIGHT,
C           USE EQUATION 3.2 IF Z = 0, OR EQ 3.1 FOR NON-ZERO Z,
C           TURNER(1970).
70      C2=2.*SZ*SZ
        IF (Z) 180,80,100
80      C3=H*H/C2
        IF (C3-50.) 90,180,180
90      A2=2./EXP(C3)
C          WADE EQUATION 3.2,TURNER(1970).
        RCZ=A2/(2.5066*SZ)
        M=1
        RETURN
100     A2=0.
        A3=0.
        CA=Z-H
        CB=Z+H
        C3=CA*CA/C2
        C4=CB*CB/C2
        IF (C3-50.) 110,120,120
110     A2=1./EXP(C3)
120     IF (C4-50.) 130,140,140
130     A3=1./EXP(C4)
C          WADE EQUATION 3.1,TURNER(1970).
140     RCZ=(A2+A3)/(2.5066*SZ)
        M=2
        RETURN
C          IF SIGMA-Z IS GREATER THAN 1.6 TIMES THE MIXING HEIGHT,
C           THE DISTRIBUTION BELOW THE MIXING HEIGHT IS UNIFORM WITH
C           HEIGHT REGARDLESS OF SOURCE HEIGHT.
150     IF (SZ/HL-1.6) 170,170,160
C          WADE EQUATION 3.5,TURNER(1970).
160     RCZ=1./HL
        M=3
        RETURN
C          INITIAL VALUE OF AN SET = 0.
170     AN=0.
        IF (Z) 180,340,190
180     RCZ=0.
        RETURN
190     A1=1./(2.5066*SZ)
        C2=2.*SZ*SZ
        A2=0.
        A3=0.
        CA=Z-H
        CB=Z+H
        C3=CA*CA/C2
        C4=CB*CB/C2
        IF (C3-50.) 200,210,210
200     A2=1./EXP(C3)
210     IF (C4-50.) 220,230,230
220     A3=1./EXP(C4)
230     SUM=0.
        THL=2.*HL
```

```
240   AN=AN+1.
      A4=0.
      A5=0.
      A6=0.
      A7=0.
      C5=AN*THL
      CC=CA-C5
      CD=CB-C5
      CE=CA+C5
      CF=CB+C5
      C6=CC*CC/C2
      C7=CD*CD/C2
      C8=CE*CE/C2
      C9=CF*CF/C2
      IF (C6-50.) 250,260,260
250   A4=1./EXP(C6)
260   IF (C7-50.) 270,280,280
270   A5=1./EXP(C7)
280   IF (C8-50.) 290,300,300
290   A6=1./EXP(C8)
300   IF (C9-50.) 310,320,320
310   A7=1./EXP(C9)
320   T=A4+A5+A6+A7
      SUM=SUM+T
      IF (T-0.01) 330,240,240
330   RCZ=A1*(A2+A3+SUM)
      M=5
      RETURN
C        CALCULATE MULTIPLE EDDY REFLECTIONS FOR GROUND LEVEL RECEPTOR H
340   A1=1./(2.5066*SZ)
      A2=0.
      C2=2.*SZ*SZ
      C3=H*H/C2
      IF (C3-50.) 350,360,360
350   A2=2./EXP(C3)
360   SUM=0.
      THL=2.*HL
370   AN=AN+1.
      A4=0.
      A6=0.
      C5=AN*THL
      CC=H-C5
      CE=H+C5
      C6=CC*CC/C2
      C8=CE*CE/C2
      IF (C6-50.) 380,390,390
380   A4=2./EXP(C6)
390   IF (C8-50.) 400,410,410
400   A6=2./EXP(C8)
410   T=A4+A6
      SUM=SUM+T
      IF (T-0.01) 420,370,370
420   RCZ=A1*(A2+SUM)
```

```
      M=4
      RETURN
C
430   FORMAT (1H0,'BOTH H AND Z ARE ABOVE THE MIXING HEIGHT SO A RELIABL
     1E COMPUTATION CAN NOT BE MADE.')
C
      END
```

XVY

```
      FUNCTION XVY (SYO,KST)
C        XVY CALCULATES THE VIRTUAL DISTANCE NECESSARY TO
C        ACCOUNT FOR THE INITIAL CROSSWIND DISPERTION.
      GO TO (10,20,30,40,50,60), KST
10    XVY=(SYO/213.)**1.1148
      RETURN
20    XVI=(SYO/155.)**1.097
      RETURN
30    XVY=(SYO/103.)**1.092
      RETURN
40    XVY=(SYO/68.)**1.076
      RETURN
50    XVY=(SYO/50.)**1.086
      RETURN
60    XVY=(SYO/33.5)**1.083
      RETURN
C
      END
```

XVZ

```
      FUNCTION XVZ (SZO,KST)
C        XVZ CALCULATES THE VIRTUAL DISTANCE NECESSARY
C        TO ACCOUNT FOR THE INITIAL VERTICAL DISPERTION.
      DIMENSION SA(7), SB(2), SD(5), SE(8), SF(9), AA(8), AB(3), AD(6),
     1AE(9), AF(10), CA(8), CB(3), CD(6), CE(9), CF(10)
      DATA SA /13.95,21.40,29.3,37.67,47.44,71.16,104.65/
      DATA SB /20.23,40./
      DATA SD /12.09,32.09,65.12,134.9,251.2/
      DATA SE /3.534,8.698,21.628,33.489,49.767,79.07,109.3,141.86/
      DATA SF /4.093,10.93,13.953,21.627,26.976,40.,54.89,68.84,83.25/
      DATA AA /122.8,158.08,170.22,179.52,217.41,258.89,346.75,453.85/
      DATA AB /90.673,98.483,109.3/
      DATA AD /34.459,32.093,32.093,33.504,36.650,44.053/
      DATA AE /24.26,23.331,21.628,21.628,22.534,24.703,26.97,35.42,47.6
     118/
      DATA AF /15.209,14.457,13.953,13.953,14.823,16.187,17.836,22.651,2
     17.074,34.219/
      DATA CA /1.0585,.9486,.9147,.8879,.7909,.7095,.5786,.4725/
      DATA CB /1.073,1.017,.9115/
      DATA CD /1.1498,1.2336,1.5527,1.6533,1.7671,1.9539/
      DATA CE /1.1953,1.2202,1.3217,1.5854,1.7497,1.9791,2.1407,2.6585,3
     1.3793/
      DATA CF /1.2261,1.2754,1.4606,1.5816,1.8348,2.151,2.4092,3.0599,3.
     16448,4.6049/
      GO TO (10,40,70,80,110,140), KST
C        STABILITY A(10)
10    DO 20 ID=1,7
      IF (SZO.LE.SA(ID)) GO TO 30
20    CONTINUE
      ID=8
30    XVZ=(SZO/AA(ID))**CA(ID)
      RETURN
C        STABILITY B (40)
40    DO 50 ID=1,2
      IF (SZO.LE.SB(ID)) GO TO 60
50    CONTINUE
      ID=3
60    XVZ=(SZO/AB(ID))**CB(ID)
      RETURN
C        STABILITY C (70)
70    XVZ=(SZO/61.141)**1.0933
      RETURN
C        STABILITY D (80)
80    DO 90 ID=1,5
      IF (SZO.LE.SD(ID)) GO TO 100
90    CONTINUE
      ID=6
100   XVZ=(SZO/AD(ID))**CD(ID)
      RETURN
C        STABILITY E (110)
110   DO 120 ID=1,8
      IF (SZO.LE.SE(ID)) GO TO 130
120   CONTINUE
```

```
      ID=9
130   XVZ=(SZO/AE(ID))**CE(ID)
      RETURN
C        STABILITY F(140)
140   DO 150 ID=1,9
      IF (SZO.LE.SF(ID)) GO TO 160
150   CONTINUE
      ID=10
160   XVZ=(SZO/AF(ID))**CF(ID)
      RETURN
C
      END
```

CURLIN

```
      SUBROUTINE CURLIN (RC,SC,R,S,Z,RAD,THETA,RL,SL,RL1,SL1,NLOCI)
C
C     THE INPUT DATA FOR CURLIN ARE THE RECEPTOR AND CENTER
C     COORDINATES,THE RADIUS OF THE CIRCLE AND THE WIND DIRECTION.
C
C     THE FUNCTION OF CURLIN IS TO DETERMINE WHERE THE LINE FORMED BY THE
C     DIRECTION AND RECEPTOR COORDINATES INTERSECTS THE CIRCLE.
C
C     R,S ARE RECEPTOR COORDINATES
C     RC,SC ARE CENTER COORDINATES
C     RAD IS THE RADIUS
C     THETA IS THE WIND DIRECTION
C     RL,SL AND RL1,SL1 ARE LOCI ON THE CIRCLE.
      RA=3.141592654/180.
      IF (THETA.EQ.0..OR.THETA.EQ.180.) GO TO 10
C
C     IF THE WIND DIRECTION IS 0 OR 180 DEGREES THAN THE RECEPTOR
C     COORDINATE CALCULATIONS FOLLOW.IF THE WIND IS FROM ANY OTHER
C     DIRECTION THAN THE RECEPTOR COORDINATE CALCULATIONS BEGIN AT
C     STATEMENT 10.
C
      GO TO 20
 10   RL=R
      RL1=R
      A=1.
      B=-2.*SC
      C=SC**2-RAD**2+(R-RC)**2
      DISC=B**2-4.*A*C
      IF (DISC.LT.0.) GO TO 50
      SL=(-B+SQRT(DISC))/(2.*A)
      SL1=(-B-SQRT(DISC))/(2.*A)
      GO TO 30
 20   IF (THETA.GT.0..AND.THETA.LE.90.) SLOPE=1./TAN(THETA*RA)
      IF (THETA.GT.90..AND.THETA.LT.180.) SLOPE=-1./TAN(180.*RA-RA*THETA
     1)
      IF (THETA.GT.180..AND.THETA.LE.270.) SLOPE=1./TAN(THETA*RA-RA*180.
     1)
      IF (THETA.GT.270..AND.THETA.LT.360.) SLOPE=-TAN(THETA*RA-RA*270.)
      DEL=-SLOPE*R+S-SC
      A=1.+SLOPE**2
      B=-2.*RC+2.*SLOPE*DEL
      C=-(RAD**2-RC**2-DEL**2)
      DISC=B**2-4.*A*C
      IF (DISC.LT.0.) GO TO 50
      RL=(-B+SQRT(DISC))/(2.*A)
      RL1=(-B-SQRT(DISC))/(2.*A)
      SL=S+SLOPE*(RL-R)
      SL1=S+SLOPE*(RL1-R)
 30   X=(RL-R)*SIN(THETA*RA)+(SL-S)*COS(THETA*RA)
C
C     X AND X1 ARE USED TO CHECK IF THE INTERSECTION VALUES ARE UPWIND.
C     IF BOTH X AND X1 ARE POSITIVE THEN THERE ARE TWO UPWIND
C     INTERSECTIONS. IF BOTH ARE NEGITIVE THEN THERE ARE NO UPWIND
```

```
C     INTERSECTIONS. IF EITHER ONE IS POSITIVE AND THE OTHER IS
C     NEGATIVE THAN THERE IS ONE UPWIND INTERSECTION.
C
      X1=(RL1-R)*SIN(THETA*RA)+(SL1-S)*COS(THETA*RA)
      NLOCI=1
      IF (X.LT.0..AND.X1.LT.0.) GO TO 50
      IF (X.LT.0.) GO TO 40
      IF (X1.LT.0.) NLOCI=0
      GO TO 60
40    NLOCI=0
      RL=RL1
      SL=SL1
      GO TO 60
50    NLOCI=-1
60    RETURN
C
      END
```

DIFANG

```
      FUNCTION DIFANG (ANGA,ANGB)
C        DETERMINES THE DIFFERENCE BETWEEN TWO ANGLES.
C        THE RESULTING ANGLE IS BETWEEN 0 AND 360 DEGREES.
      DIFANG=ANGA-ANGB
      IF (DIFANG) 10,40,50
10    IF (DIFANG+180.) 20,30,40
20    DIFANG=DIFANG+360.
      GO TO 10
30    DIFANG=180.
40    RETURN
50    IF (DIFANG-180.) 40,30,60
60    DIFANG=DIFANG-360.
      GO TO 50
C
      END
```

ANGARC

```
      FUNCTION ANGARC (DELM,DELN)
C         ANGARC DETERMINES THE APPROPRIATE ARCTAN(M/N) WITH
C         THE RESULTING ANGLE BETWEEN 0 AND 360 DEGREES.
      IF (DELN) 10,40,80
10    IF (DELM) 20,30,20
20    ANGARC=57.29578*ATAN(DELM/DELN)+180.
      RETURN
30    ANGARC=180.
      RETURN
40    IF (DELM) 50,60,70
50    ANGARC=270.
      RETURN
60    ANGARC=0.
      RETURN
70    ANGARC=090.
      RETURN
80    IF (DELM) 90,100,110
90    ANGARC=57.29578*ATAN(DELM/DELN)+360.
      RETURN
100   ANGARC=360.
      RETURN
110   ANGARC=57.29578*ATAN(DELM/DELN)
      RETURN
C
      END
```

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